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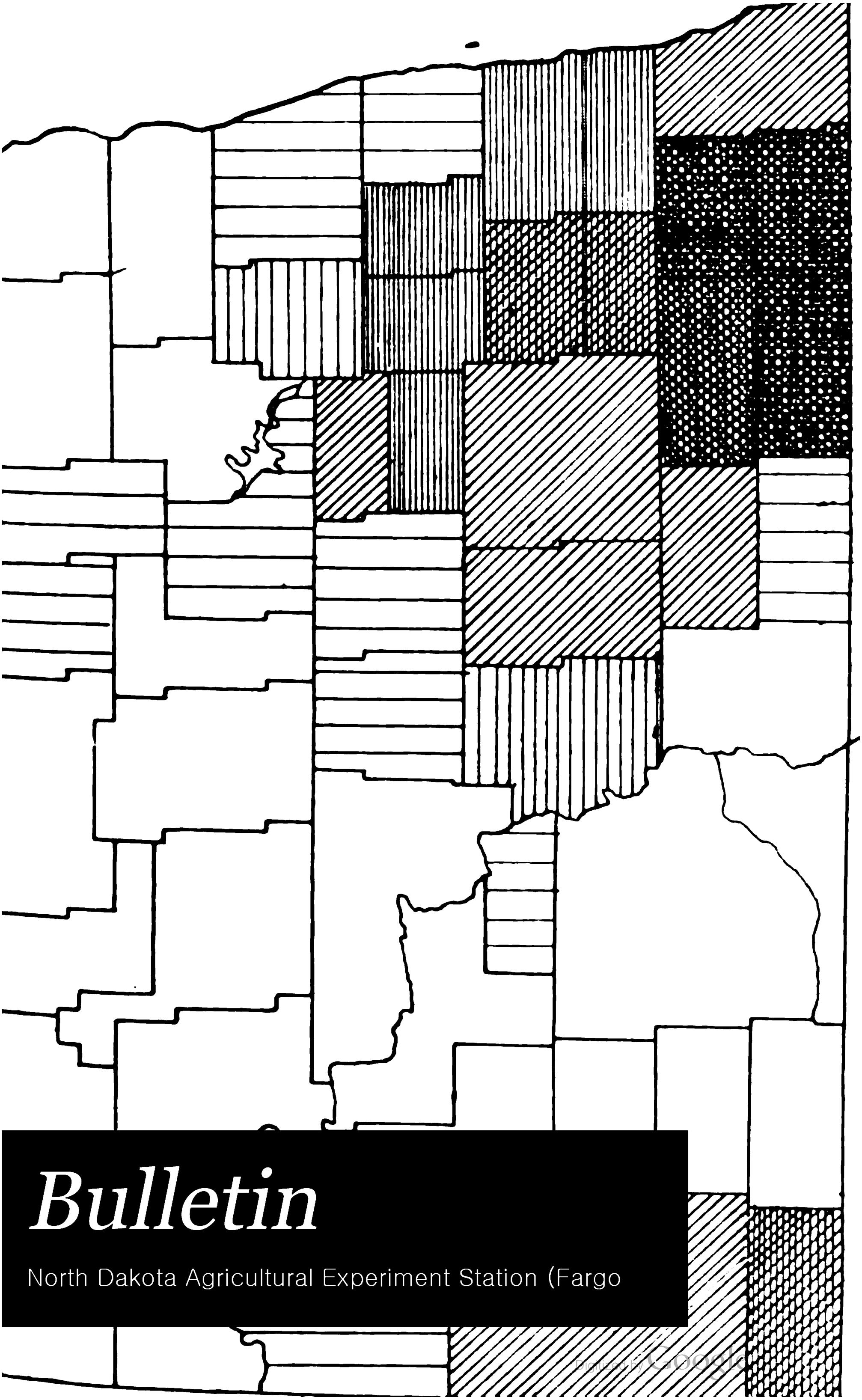

Bulletin

North Dakota Agricultural Experiment Station (Fargo

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NORTH DAKOTA AGRICULTURAL COLLEGE
GOVERNMENT AGRICULTURAL
EXPERIMENT STATION
FOR
NORTH DAKOTA

Bulletin No. 91

DAIRY HERD RECORDS

(A) Studies in Cost of Production
(B) Individual Types
(C) Individual Feed Requirements

BY

J. H. SHEPPERD and W. B. RICHARDS

Any farmer, teacher, or student in the State may have this Bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
1911

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DAIRY HERD RECORDS

(A) Studies in Cost of Production.
(B) Individual Types.
(C) Individual Feed Requirements.

By J. H. SHEPPERD AND W. B. RICHARDS

This bulletin presents to the public the records of the college herd from 1904 to 1910 and the results of special studies made upon the cows composing it during that time. The herd has not been large within this interval; never numbering over fifteen cows in milk at one time. The herd has been increased from the offspring of a few grade cows that were purchased by this station in 1893, and by some purchases of pure breds made from time to time. Complete record of the milk production of twenty-four different cows has been kept during this time, but record of the fat produced and the feed consumed has only been kept since June 16th, 1907. The twenty-four cows represent the following grades and pure breds.

2 pure bred Holstein,
3 pure bred Jerseys,
4 pure bred Red Polls,
1 pure bred Shorthorn,
4 grade Holsteins,
8 grade Jerseys.

A description of each cow will follow and photographs of several are presented to help the reader formulate an idea of the type of cows that have been studied. It should be said at the outset that most of the grade cows were very ordinary in form and blood lines — no better than a good many of our farmers have in their herds. Some of them, however, regardless of the fact that they possess little improved blood have proven themselves to be good producers — under the care and management they received.

The records of the herd are given in two ways. What is called the yearly record, includes the production of the herd and food consumed for the calendar year, regardless of the lactation period. What is called the lactation period, includes the production of the cows in the herd from the time of freshening until they dry up. It is desirable to know the results in both ways, for the yearly record shows what profit the herd or any individual in it has net each year, while the lactation period shows how much a cow can produce during her lactation period or during her yearly period of milk flow.

CARE AND MANAGEMENT

The herd was fed and cared for in such a manner as to insure as large returns as possible under the conditions we had at our disposal.

The cows were kept in the barn during the entire winter, except for a short time each day when they were getting water, possibly, one hour each day on the average. The length of time they were out depended upon the weather. When the weather was stormy or cold they were not allowed to remain out more than a few moments. They were provided with comfortable stalls and kept well bedded at all times.

The following schedule was followed closely in caring for the herd:

5:00 A. M.	Grain fed.
5:15 A. M.	Milking begun.
6:30 A. M.	Silage fed.
9:00 A. M.	Watering and stables cleaned and bedded.
10:00 A. M.	Hay fed, and cows groomed.
3:30 P. M.	Water and stables cleaned.
4:00 P. M.	Grain fed.
5:00 P. M.	Milking begun.
5:45 P. M.	Silage fed.

The writers wish to acknowledge the service rendered by John McDonald and Wm. Lanxon who acted as herdsmen and cared for the cows during the years covered by the records given in this bulletin. What success was obtained with the cows in the herd was due to a large extent to the diligence with which they performed their duty. We were also ably assisted by Prof. G. L. Martin in compiling the tables, to whom we are indebted for his service.

Winter Feeding: The cows were fed silage and hay, consisting chiefly of timothy and millet, although sometimes hay consisting of clover and timothy mixed was used. The limited amount of clover and alfalfa hay grown on the college farm has always been reserved for the sheep, consequently the dairy cows have not received the benefit of these excellent milk producing forage crops which were at hand. The grain ration consisted of bran and shorts and a small amount of barley, oats and corn. Oil meal has been fed in a few instances, where cows needed special feeding to secure good results. Some roots have been fed as the table of the feed records indicate.

Summer Feeding: The herd has been kept on timothy and brome grass pastures the entire summer each year and during the period covered by these records it was not found necessary to supplement the pastures to any extent with any form of soiling crop, or even silage, except near the end of the pasture season. The pastures on the college farm were very luxuriant during the summers covered by these records. Silage has been kept on hand nearly every summer to feed in case the pastures should run short. Some years it has been found necessary to feed silage as early as September 15th, or as soon as the silo has been filled. The same kinds of grain feeds have been fed during the summer as during the winter months.

The rainfall during the period covered by this bulletin, was so abundant during the pasture seasons, that there was no scant pasture at any time. This condition is unusual and can not be expected to prevail regularly in the future.

SYSTEMS OF FEEDING

No attempt was made to compare different kinds of rations, but the feeds most available for the farmers of this state were fed, as will be seen by the list of feeds given in the tables. The quantity of feed fed, was adjusted so as to produce the greatest returns, using as a guide the condition of the cows and their weekly records.

Each cow was weighed every week since record has been kept of the food consumed and butter fat produced by each cow. The weights of the cows were watched to see if they were putting on too much fat or dropping off in weight. When they were getting too fleshy the amount of the grain was reduced and the proportion of protein increased in the ration, by increasing the proportion of bran to the other feeds given. By this means we reduced the fleshing tendency of the rations when necessary. Bran is a feed rich in protein and is a good milk producer and not a fat maker. The rule followed in determining the amount each cow was fed, was to supply all the silage and hay they would eat up clean and in addition the amount of grain that was necessary to make them produce the largest quantity of milk they were capable of doing. The grain was decreased as soon as it was found that the cow did not increase her flow of milk. No two of these cows under the same conditions could be fed just alike and get the best results. Each individual is a little different in her requirements, from any other and if they are made to produce the largest quantity of milk they are capable of doing they must be fed according to their individual requirements.. The composition of the ration that is fed to different cows should be varied to meet their requirements and the character of the ration they should be fed will depend upon their temperament. It was necessary to feed the cows that possessed a tendency to fatten, a grain ration containing a larger proportion of bran, and to those possessing a tendency to reduce their weight, a larger proportion of shorts, while several of the cows tending to lose weight and run low in flesh were fed corn, oats or barley for longer or shorter intervals. as their individual cases required.

The grain and roughage were weighed out separately, each feeding time, on convenient scales for the purpose. The cows were weighed every Wednesday morning, the day on which the new week for keeping record began. These records included the weekly milk production, and butter fat which latter was secured by taking composite samples and testing for butter fat by means of the Babcock test.

METHODS OF KEEPING RECORDS

The cows were milked at practically the same hour morning and evening during the year. Regularity in the time of milking should be practiced, for better results can be obtained than if they are milked at different times of the day. If a cow has been in the habit of getting milked at a certain time she is disappointed if she is not milked at that time and seems affected as much as if she is not fed at the regular time.

The plan used for keeping a record of the milk yield was not different from the method used by most dairymen who keep records of the yields of the individual cows in the herd. The milk of each cow was weighed as the milking was done and recorded on what is known as a milk sheet, designed for a weekly period. A small but definite sized sample of each cow's milk was taken at every milking and placed in a pint jar with the name of the cow indicated upon it. This composite sample of each cow's milk was tested at the end of the week for butter fat. By multiplying the per cent of butter fat in the cow's milk by the amount of milk produced during the week the amount of butter fat is determined. The weekly milk and fat to each cow's credit, with the feed she consumed during the week were recorded at the end of each weekly period in the herd record book especially made for that purpose.

Every dairyman should keep the record of the production of the herd in the manner described above, only possibly varying it by keeping monthly composite samples of milk instead of weekly ones. Even testing a sample of the night and morning milking, one day each month for each cow for the average per cent of fat, can be used for determining the fat yield for the month, and will answer quite well for the practical purpose of determining the good and poor cows in the herd.

The annual production and feed consumed by the herd for two years only are given in the tables which follow, and cover the years, Jan. 1st, 1908, to Jan. 1st, 1910. The records of the butter fat produced and of the feed consumed were not kept prior to June 19th, 1907. For that reason only two complete year's record of the milk yield, butter fat produced and feed consumed are given. The milk yields of the cows in the herd from 1904 to 1908 are also given in the tables.

VALUE OF FEED AND PRODUCTS

The net profit each cow has made for the calendar years 1908 and 1909, and during the year of their maximum production, has been determined based on a schedule of prices adopted for the feed consumed and for the value of the products. The prices of the feeds used are based upon the average market price that has prevailed for those feeds during the past six years in this state. These prices are no doubt somewhat higher than the prevailing prices for these products on most North Dakota farms. It is impossible to get a schedule of prices that will suit all local conditions. This, however, is of minor importance, as the object of these records is chiefly to show the comparative economy of production between the different cows in the herd. We believe, however, that the prices of the feeds compare favorably with the prices the dairy products were rated at for the same period. The prices of feed will fluctuate from year to year and it is impossible to use the figures for calculating results with a herd for any one year, but on the other hand the results show what is to be expected for an average of several years. This, in fact, is the best basis from which to figure.

The value given silage is the estimated cost of production in the State of Minnesota as published in Bulletin 97, "The Cost of Producing Farm Products."

In determining the value of the products produced by the cows the butter is determined by multiplying the butter fat by one and one-sixth, which is the customary basis for calculation in practice. The skim milk credited to each cow is determined by taking 80% of the whole milk. A value of twenty cents per hundred is given to skim milk for feeding tests show that it is worth this much, if not more, for feeding purposes at the price for feed prevailing at the present time. The net profit for each cow was then determiend by taking the difference between the cost of the feed consumed by the cows, and the value of the products to her credit.

Schedule of prices of feed and products:

Hay	$ .30	per hundred
Corn silage	.09	per hundred
Pasture	4.00	per season
Wheat Bran	.90	per hundred
Shorts	.90	per hundred
Oats	.90	per hundred
Barley	.90	per hundred
Corn	.80	per hundred
Oil meal	1.30	per hundred
Butter	.30	per pound
Skim milk	.20	per hundred

DESCRIPTION AND DATA REGARDING THE COWS IN THE COLLEGE HERD, 1904-1909

In order to get in a concise form the facts regarding the breed of the cows in the herd and their ages when they made their year's record the following table has been prepared.

Table I.— List of Cows in College Herd, 1904-1910

Name of Cow	Breed	Age at Beginning of Record	Dates of Calving					
			1904	1905	1906	1907	1908	1909
Lucy	Grade Holstein	8*	April 6	May 11	....	....	....	....
Vina	Grade Holstein	10*	Feb. 7	Aug. 20	....	Feb. 20	....	....
Goldie's Wilda	P. B. Jersey	8	Feb. 7	Mar. 15	Sept. 7	....	Jan. 9	....
Recorder's Gem	P. B. Jersey	9	Feb. 12	May 15	July 25	Oct. 27	....	Feb. 20
Pet	Grade Jersey	12*	April 12	....	....	....	....	....
Sunstroke	P. B. Red Poll	10	Oct. 17	....	....	....	....	....
Princess Teake	P. B. Holstein	7	....	....	....	Mar. 13	July 14	....
Daisy	Grade Jersey	4	Jan. 15	April 11	May 19	July 25	....	....
Lucy 2d	Grade Jersey	2	....	....	April 25	July 23	....	....
Clara 2d	Grade Jersey	2	....	....	April 21	June 19	....	....
School Girl	P. B. Short-Horn	3	....	....	Dec. 17	....	....	....
Gem 3d	Grade Jersey	2	....	....	Mar. 23	June 12	....	....
Lena	Grade Holstein	6*	....	....	Sept. 18	Nov. 26	....	July 11
Millie	Grade Jersey	2	....	....	....	May 21	....	....
Linna	P. B. Red Poll	1½	....	May 13	May 14	July 29	....	April 13
Bess	Grade Holstein	7*	....	....	....	....	April 27	Aug. 2
Vina 3d	Grade Jersey	2	....	....	....	....	July 16	....
Daisy 2d	Grade Jersey	2	....	....	....	....	Aug. 24	....
Zizos Lady	P. B. Red Poll	2	....	....	....	....	Aug. 31	....
Gem's Brown Bessie	P. B. Jersey	3	....	....	....	....	July 27	Aug. 9
Miss Sunstroke	P. B. Red Poll	3	....	....	....	....	....	June 21
Madison Miss Ormsby	P. B. Holstein	2	....	....	....	....	....	Mar. 10
Tibby	Grade Jersey	2	....	....	....	....	Dec. 12	......
Nettie 2d	Grade Jersey	2	....	....	....	....	Nov. 2	....

*Real age not certain. This figure an estimate.

In order to get the most out of studying the following tables which contain the records of the production of the cows in the herd the reader should know something about the type, conformation and history of each of the cows. To acquaint the reader with the cows a description of each one and photographs of most of them have been prepared. The cows whose photographs do not appear were sold and no photographs taken of them before they left the herd. The photographs of the cows appear on the pages opposite the descriptions, which will enable the reader to readily study the cow discussed.

DESCRIPTION OF COWS

PET

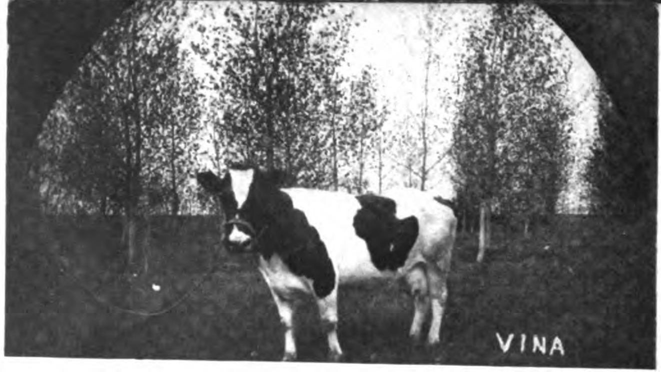
The age of Pet is not known definitely. She was bought by an itinerant cattle buyer for the Station in 1894 but there is good evidence that she was over 12 years of age when she made her first record given in this bulletin. She died Aug. 27, 1906, of old age. Pet showed some indication of having a cross of Jersey blood, but did not show pronounced Jersey characteristics. She showed marked dairy type and much dairy tendency, was a very persistent milker and a good producer as her records will show.

VINA

Her age also is not definitely known, for she was bought in the same lot as Pet in 1894. There is good evidence she was over ten years of age at the time her first record was made as recorded in this bulletin. She died May 14, 1906, of heart failure. She evidently possessed considerable Holstein blood —was alleged to be an unregistered full blood. She was a large, robust cow, having a great capacity, a large well developed udder, and was a persistent milker.

LUCY

She was secured in the same lot with Pet and Vina and her age is indefinite. She was at least ten or twelve years old in 1904 when our records begin. She possessed some Holstein and was alleged to have a little of Jersey blood, otherwise she was of common breeding as far at the writers know. She was a medium sized cow with a nearly perfect dairy form and possessed a marked dairy tendency. The photograph does not do her justice as it was taken near the end of her lactation period prior to 1904. She was killed in November, 1908, on account of the loss of one quarter of her udder, and a general physical decline. Her production for 1908 was very low because of the defect in her udder. Her records on previous years, however, indicate that she was an excellent producer.



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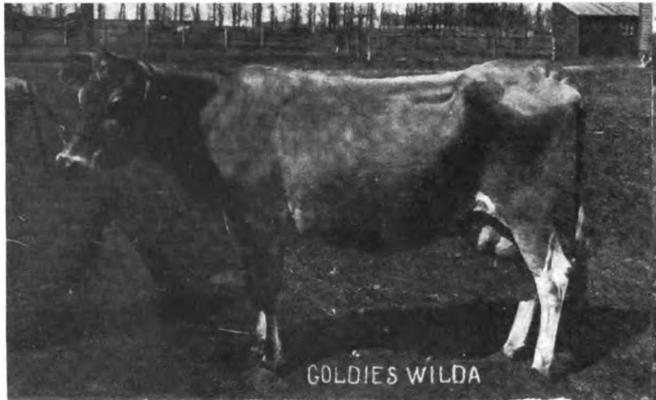
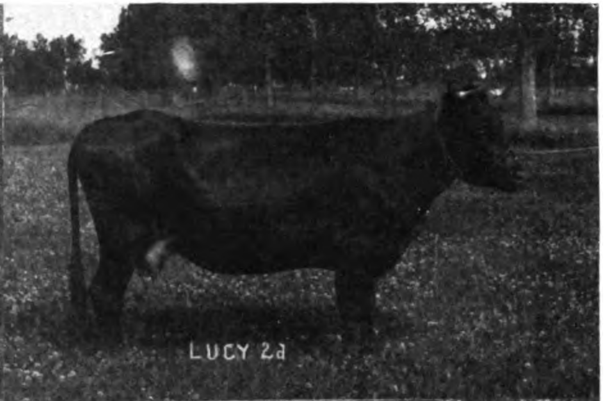


GOLDIES WILDA



LUCY 2d

CLARA 2d

RECORDER'S GEM

GOLDIE'S WILDA

She was a pure bred Jersey, and died of milk fever in March, 1909, at twelve years of age. She was bred by H. G. McMillian of Rock Rapids, Iowa, and was bought by this Station on Dec. 14, 1898. The accompanying photograph does not do her justice, as it was not well taken. She was a very typical Jersey of excellent conformation. She was inclined to show a little tendency to lay on fat at times. She had a well shaped udder. She was a persistent milker, and one of the profitable cows in the herd as the tables indicate.

RECORDER'S GEM

She is a pure bred Jersey; age fourteen years, and still in the herd. She was also bred by H. G. McMillian, Rock Rapids, Iowa, and bought by the Station on Dec. 14, 1898. She is a very small cow but has a good typical dairy form. At the present time she shows a decided lack of beefiness, but when younger she fleshed considerably. Her udder is rather deficient in form and quality. Her skin is rather coarse and free from pliableness. She must be criticised as lacking constitution, and for extreme delicacy.

LUCY 2D

She is also a daughter of Lucy, sired by a Jersey bull, and is five years old. She is more of a dairy type, than Daisy, but lacks dairy tendency. She is too coarse over the shoulders and too thick in the thighs, to meet the requirements of the dairy type. She did not freshen from July 18th, 1907, to Feb. 7, 1910, but aborted twice within that time which has interfered with her production. Her udder is not as well developed as it should be in front, and it is also somewhat meaty.

CLARA 2D

This cow is five years of age, sired by a pure bred Jersey bull out of a common cow. This cow is very much the same in type as Lucy 2d, only she is still coarser over the shoulders, and thicker in the thighs. Her udder is also somewhat deficient in development and quality. She did not freshen from June 19th, 1907 to April 4th, 1910, and has been milking continuously since, but aborted once in the meantime.

PRINCESS TEAKE

A pure bred Holstein, nine years of age. She was bred by Jos. Glennie, Longburn, Man., Canada, and purchased of Geo. P. Grout, Parkdale, Man. She is a large upstanding animal and lacks the capacity one would expect to see in such a large cow. Her udder is small, yet it is well proportioned, and she produces better than one would expect, judging from the size of her udder. She is proving a very profitable cow in the herd.

LENA

She is a high grade Holstein cow. Her age is not definitely known, but she is probably seven or eight years of age. She was bought of a farmer near Fargo, in September 1906. In conformation, Lena is very typical of the Holstein type. She is a little smaller than the average of the breed and lacks the requisite refinement about the head. Her udder is large, but is cut up too much between the quarters. She did not freshen from November 26, 1907 to July 11th, 1909, but aborted in the meantime.

MADISON MISS ORMSBY

Madison Miss Ormsby is a pure bred Holstein and was only twenty-two months old when she freshened in 1909. She is of a refined dairy type and showed unusual promise of being a high producer when she freshened in 1909, but went off her feed a few weeks after calving and did not recover her original flow of milk, otherwise she would undoubtedly have made a good record as a first calf heifer. She was purchased when about eighteen months of age of Leonard W. Gay, Madison, Wis.

DAISY 2D

Daisy 2d is a daughter of Daisy and is therefore a three-fourths blood Jersey. She was three years of age May 19th, 1909. She is a heifer that has a good conformation, showing considerable dairy tendency.

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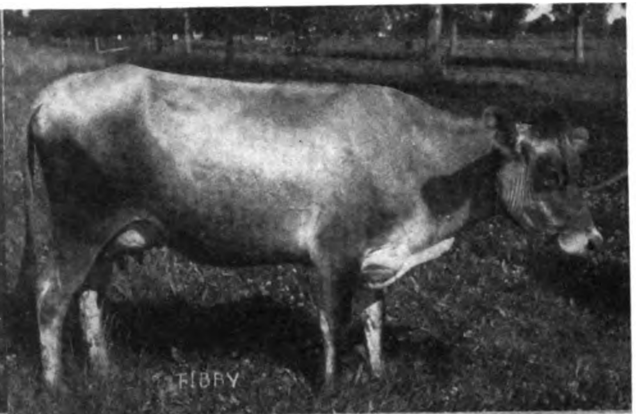
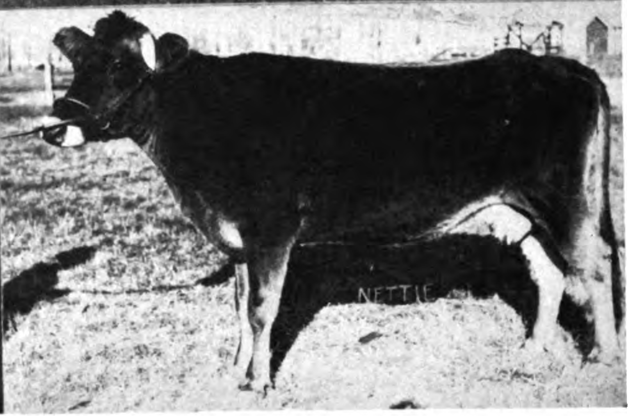




VINA 3D

A grade Jersey; two years of age. She has a good dairy form with considerable dairy tendency. She has also quite a well developed udder.

TIBBY

She is a grade Jersey heifer, and was two years old when she was in milk, the year her record is given in this bulletin. She was raised at this station. She is a three-fourths bred Jersey and has a good dairy form with a fairly good sized, well developed udder.

NETTIE 2D

Nettie 2d is a daughter of Nettie, sired by a Jersey bull. She was two years of age when she made her record given in this bulletin. She is a heifer with a rather poor conformation. She lacks depth of barrel or digestive capacity, otherwise she shows many very desirable points. Her dairy temperament and quality are good. She was raised at this station.

GEM'S BROWN BESSIE

She is a pure bred Jersey and a daughter of Recorder's Gem. Age four years. She is too short and thick-necked, with a tendency throughout to show beefiness. She is disappointing as a producer.

LINNA

A pure bred Red Polled, five years of age, and bought with Sunstroke in October, 1904. She was bred by accident, and proved to be in calf, which was discovered a short time after she was purchased. She calved when only seventeen months of age. This retarded her growth so that she is not as large as she would otherwise have been. She is a rather thick, blocky type and never shows a very marked dairy form or tendency. She would have produced greater returns if she had not freshened so young. Her records indicate that she is improving each year.

ZIZO'S LADY

She is a pure bred Red Polled; a daughter of Linna Age three years. She has more of a dairy type than her dam. She is rather prominent over the shoulder and back. Her neck shows considerable of the refinement, character istic of a cow of dairy tendency. Her udder is fairly well developed and is good in quality.

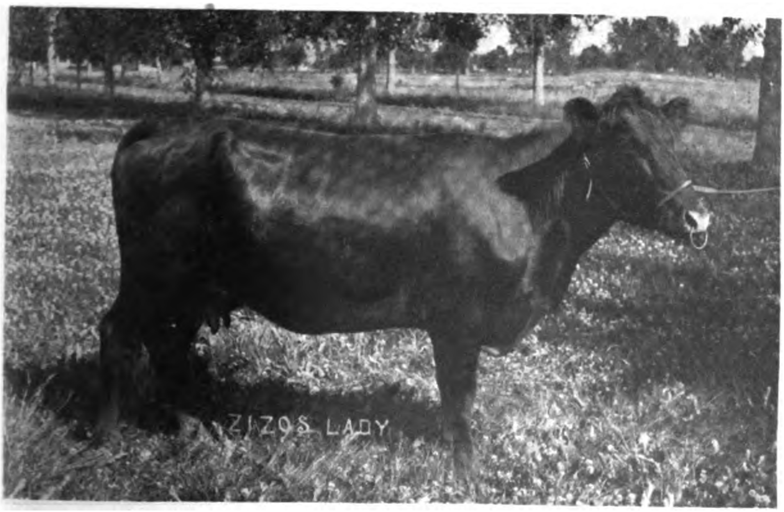
SCHOOL GIRL

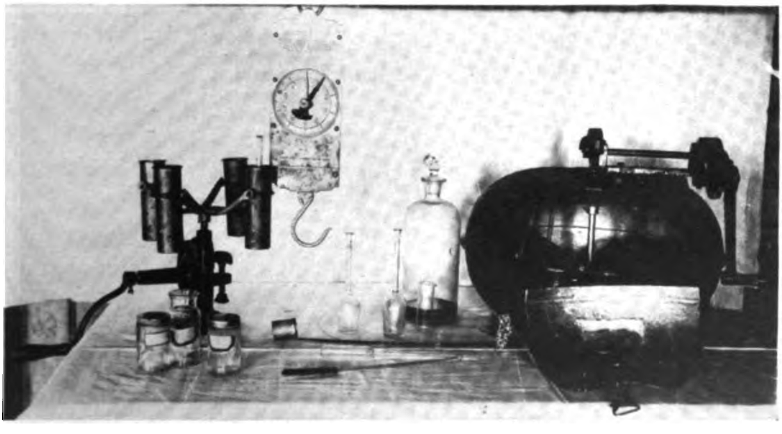
School Girl is a pure bred Short-horn and carries considerable Scotch blood; age six years. She was only a three year year old when she made her year's record in the herd. She is a blocky, compact cow and possesses to a high degree the form and quality of a beef animal. During her lactation period, however, she reduces her flesh considerably. By accident her second calf was allowed to suckle her, and she was never returned to the dairy herd, which is to be regretted, as she gave promise of developing into a good milker and an ideal dual purpose cow.

SUNSTROKE

A pure bred Red Polled cow, purchased October 12th, 1904, from Wheelock & Wheelock, Fargo, N. Dak. She was bred by W. H. Haylet, Leon, Iowa. She was calved July 1st, 1894, making her ten years of age when she came to the herd. She had not received good care before we got her and calves had been allowed to suckle her, for this reason no large or economic production could be expected of her, She was bought for the offsprings she would raise,

LINNA


ZIZOS LADY



Apparatus neccesary for keeping record of production of the cows in the herd. Two types of Babcock testers are shown, the large and small.

MISS SUNSTROKE

Miss Sunstroke is a pure bred Red Polled cow and a daughter of Sunstroke. She was three years old at the time her record given in this bulletin was made. She was a very compact, smooth and symmetrical heifer when she freshened, but towards the end of her lactation period she began to show more of a dairy form. Her ration during her lactation period was kept high in protein because she showed so much fleshing tendency. Her udder does not show much development, but may improve.

GEM 3D

Gem 3d was a grade Jersey. She was a two year old when she made her first yearly record as given in this bulletin. She was sold to the butcher January 20th, 1908, because she reacted to the tuberculin test. Even if she had not reacted she would have been discarded from the herd as she was not proving a profitable producer. She was rather coarse over the shoulders, and lacked depth of barrel, with a tendency to carry considerable flesh during the lactation period.

DAISY

She is a daughter of Lucy, sired by a Jersey bull, born March 14th, 1900, and was sold to the butcher May 6th, 1908. She was a large cow with a pronounced beefing tendency. She never proved to be a very persistent milker and was discarded from the herd for that reason.

BESS

Bess is a recent acquisition to the herd. She was purchased in March, 1908, from a farmer near Fargo, She is a cow which has never had more than ordinary care. She is about seven years of age. Her appearance would indicate that she possesses some Holstein blood.

MILLIE

This cow is a grade Jersey; age four years. She was discarded from the herd recently. She was a coarse, fleshy type, and never gave promise of being a good producer. Her milk, however, tested very high in butter fat, her yearly average was 5.97 per cent, but she gave a rather small quantity of milk.

THE YEARLY HERD RECORDS FROM 1904-1910

As stated before it was thought advisable to compile the records of the production and feed consumed by the cows in the dairy herd in two ways. First, to show the results produced by the herd for each calendar year from January 1st to January 1st, the succeeding year, and second, to show the results produced by the cows during their lactation periods each year. The reason for giving the records of the herd for the calendar year is because the profits produced by the cows calculated from this basis represents more accurately the profit a cow nets the owner. On this basis the cows are credited with the exact amount of butter fat they produced each consecutive year regardless of the length of time they were in milk. They are also charged with the cost of the feed they consumed during the whole of the year. The cows must be fed, while they are dry and the expense of keeping them during this time should be charged against them as it enters into the cost of production for the year. For the reasons given above the results obtained with the herd will be given for the calendar year, which should be the basis for drawing conclusions relative to the profit that was derived from the cows in the herd each year.

It was also considered necessary to publish tables showing how much the cows produced during their lactation periods; that is, from time of freshening to time of drying up. This shows what a cow is capable of producing during her lactation period, which is the standard method practiced for comparing the productive capacity of cows. The net profit figured from this standpoint, however, does not represent a true statement of the profit the cow nets the owner, as a commercial undertaking. Compiling the results of production and feed consumed by the cows from the basis of the lactation period, however, is necessary in order to determine accurately the amount of feed and nutrients required for producing a given quantity of butter fat.

The following tables give the production, feed consumed, and net profits produced by the cows in the herd during the calendar year from 1908-1910. The milk produced is given, however, from 1904. Record of the butter fat produced by the cows and the feed consumed was not kept before June 17th, 1907, which accounts for the omission of this data in the tables during the years previous to this time.

Table II. — Annual Production per Cow per Year, 1904--1910.

Name of Cow	Year	Days in Milk	Production				Value of Prod'ts	Cost of Feed	Net Profit
			Milk	Fat	Fat	Butter			
			Lbs.	Per ct	Lbs.	Lbs.			
Goldies Wilda..	04–05	358	7286.5	......	......	......	......	......	......
" " ..	05–06	317	7366.2	......	......	......	......	......	......
" " ..	06–07	309	6203.6	......	......	......	......	......	......
" " ..	07–08	311	5049.6	......	......	......	......	......	......
" " ..	08–09	356	6899.4	4.1	288.7	336.8	$112.08	$44.18	$67.90
Average...		330	6561.0						
Vina..........	04–05	330	12664.2	......	......	......	......	......	......
"	05–06	260	8515.3	......	......	......	......	......	......
"	06–07	338	8905.0	......	......	......	......	......	......
Average...	.....	309	10028.1						
Lucy..........	04–05	275	8352.0	......	......	......	......	......	......
"	05–06	319	7461.5	......	......	......	......	......	......
"	06–07	333	5119.5	......	......	......	......	......	......
"	07–08	259	3371.6	......	......	......	......	......	......
Average...	.....	296	6076.1						
Recorder's Gem	04–05	316	5257.5	......	......	......	......	......	......
" "	05–06	273	4001.8	......	......	......	......	......	......
" "	06–07	296	3273.7	......	......	......	......	......	......
" "	07–08	303	2824.6	......	......	......	......	......	......
" "	08–09	315	3748.1	5.0	188.7	219.6	$71.87	$41.10	$30.77
" "	09–10	314	4216.8	5.0	213.7	249.3	$81.53	$27.02	$54.51
Average...	.....	303	3871.9		201.2	234.4	$76.70	$34.06	$42.64
Princess Teake.	07–08	297	8641.4	......	......	......	......	......	......
" "	08–09	303	8022.9	2.9	236.7	276.2	$ 95.69	$45.38	$50.31
" "	09–10	320	8400.7	3.0	259.8	303.1	$104.37	$35.74	$68.63
Average...	.....	307	8355.0		243.2	289.6	$100.03	$40.56	$59.47

Table II. — Annual Production per Cow per Year, 1904—1910—Continued

Name of Cow	Year	Days in Milk	Production				Value of Prod'ts	Cost of Feed	Net Profit
			Milk	Fat	Fat	Butt'r			
			Lbs.	Per ct	Lbs.	Lbs.			
Sunstroke	04–05	78	1132.7	......	.....	......	....	......	......
“	05–06	165	2055.7	......	.....	......	....	......	......
Average	.....	121	1594.2						
Daisy	04–05	316	4955.0	......	.....	......	....	......	......
Vina 3rd	09–10	.....	2850.3	4.3	123.2	143.7	$ 47.67	$22.18	$25.4
Madison Miss Ormsby	09–10	296	5757.5	3.2	189.6	221.2	$ 75.57	$17.21	$58.3
Lucy 2nd	06.07	245	3070.0	......	.....	......	....	......	......
“ “	07–08	274	3519.3	......	.....	......	....	......	......
“ “	08–09	365	5589.8	5.9	332.0	387.3	$108.55	$41.65	$66.9
“ “	09–10	286	3843.1	5.3	204.7	238.8	$ 77.78	$25.38	$52.4
Average	.....	292	4005.5		268.3	313.0	$ 93.17	$33.51	$59.6
Gem 3rd	06–07	278	3321.3	......	.....	......	....	......	......
“ “	07–08	318	3934.8	......	.....	......	....	......	......
“ “	08–09	287	3212.3	4.6	149.3	174.1	$ 57.36	$32.14	$25.2
Average	.....	294	3489.4						
Clara 2nd	06–07	245	3243.8	......	.....	......	....	......	......
“ “	07–08	313	4732.1	......	.....	......	....	......	......
“ “	08–09	365	6354.7	4.2	266.9	311.3	$103.55	$43.26	$60.2
“ “	09–10	328	3356.9	5.5	184.4	215.2	$ 69.87	$24.76	$45.1
Average	.....	346	4855.8		225.1	263.2	$ 86.71	$34.01	$52.7
Linna	05–06	228	3599.2	......	.....	......	....	......	......
“	06–07	339	4528.5	......	.....	......	....	......	......
“	07–08	223	3191.6	......	.....	......	....	......	......
“	08–09	358	3662.8	4.1	153.0	178.5	$ 59.41	$38.57	$20.8
“	09–10	254	5365.3	3.6	193.9	226.2	$ 66.44	$31.43	$35.0
Average	.....	280	4069.5		173.4	202.3	$ 62.92	$35.00	$27.9
Millie	08–09	365	2758.4	5.9	164.8	192.2	$62.11	$41.64	$20.4
Bess	09–10	276	4547.6	......	182.5	212.9	$ 71.54	$30.16	$41.3
Lena	07–08	319	6450.8	......	.....	......	....	......	......
“	08–09	365	8314.3	3.1	250.6	292.3	$101.00	$45.92	$55.
“	09–10	257	4929.0	3.0	150.7	175.8	$ 60.62	$29.77	$30.
Average	.....	313	6564.7		200.7	234.0	$ 80.81	$37.84	$42.

Table II. — Annual Production per Cow per Year, 1904--1910.— Continued

Name of Cow	Year	Days in Milk	Production				Value of Prod'ts	Cost of Feed	Net Profit
			Milk	Fat	Fat	Butt'r			
			Lbs.	Per ct	Lbs.	Lbs.			
Daisy 2nd......	09–10	333	4893.7	4.9	230.5	269.0	$ 87.95	$29.40	$58.55
Zizo's Lady	09–10	295	4329.3	4.1	179.9	209.9	$ 69.89	$28.27	$41.62
School Girl.....	07–08	310	5217.1	......	.....	......	....	......	......
Gem's Brown Bessie.......	09–10	338	1784.9	8.2	147.1	171.6	$ 54.33	$22.52	$31.81
Tibby.........	09–10	365	5149.6	4.6	238.2	277.9	$ 91.60	$26.73	$64.87
Nettie 2nd.....	09–10	296	3151.2	4.3	135.6	158.2	$52.50	$26.32	$26.18

Table III. — Summary of the Production of the Herd, 1908--1910.

Name of Cow	Breed	Age Years	No. of Yrs	Average days in Milk	Milk lbs.	Fat %	Fat lbs.	Butter lbs.	Value of Prod'cts	Net Profits
Goldies Wilda........	Jer.	12	1	356	6899.4	4.1	288.7	336.8	$112.08	$67.90
Tibby...............	Gr. Jer.	2	1	365	5149.6	4.6	238.2	277.9	$91.60	$64.87
Lucy 2nd............	Gr. Jer.	3 — 4	2	325.5	4716.4	5.6	268.3	313.0	$93.17	$59.65
Princess Teake.......	Hol.	9	2	311.5	8211.8	2.9	243.2	289.6	$100.03	$59.47
Daisy 2nd...........	Gr. Jer.	2	1	333.	4893.7	4.9	230.5	269.0	$87.95	$58.55
Madison Miss Ormsby	Hol.	2	1	296.	5757.5	3.2	189.6	221.2	$75.57	$58.36
Clara 2nd...........	Gr. Jer.	3 — 4	2	346.5	4855.8	4.6	225.1	263.2	$86.71	$52.70
Lena................	G. Hol.	7	2	313.6	6564.7	3.0	200.7	234.0	$80.81	$42.97
Recorder's Gem......	Jer.	12 — 13	2	314.5	3982.4	5.8	201.2	234.4	$76.70	$42.64
Zizos Lady..........	R. P.	2	1	295.	4329.3	4.1	179.9	209.9	$69.89	$41.62
Bess................	Gr. Hol.	7	1	276.	4547.6	4.0	182.5	212.9	$71.54	$41.38
Gem's Brown Bessie..	Jer.	3	1	338.	1784.9	8.2	147.1	171.6	$54.33	$31.81
Linna	R. P.	4 — 5	2	306.	4514.0	3.9	173.4	202.3	$62.92	$27.92
Nettie 2nd..........	Gr. J.	2	1	296.	3151.2	4.3	135.6	158.2	$52.50	$26.18
Vina 3rd............	Gr. J.	2	1	365.	2850.3	4.3	128.2	143.7	$47.67	$25.49
Gem 3rd.............	Gr. J.	3	1	287.	3212.3	4.6	149.3	174.1	$57.36	$25.22
Millie..............	Gr. J.	2	1	365.	2758.4	5.9	164.8	192.2	$62.11	$20.47

Table IV. — Feed Consumed per Cow per Year, 1908--1910.

Name of Cow	Year	Timot'y Hay	Clover Hay	Prairie Hay	Millet Hay	Silage	Bran	Shorts	Bar-ley	Oats	Corn
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Goldies Wilda........	08–09	594.0	....	290	1331.0	8768.	2007.0	458.0	195.2	12	192
Recorder's Gem......	08–09	594.0	....	350	1321.	7049.5	1914.5	449.0	112.	24	150
" "	09–10	710.	215.0	170	185.	4722.0	810.5	849.5	......	......	......
Average........	.....	652.	107.5	260	753.	6885.7	1362.5	649.2	56.	12	75
Princess Teake......	08–09	673.	....	336	1317.0	10160.	2106.8	396.0	195.2	12	160
" "	09–10	803.	105.0	204	222.0	9815.0	903.0	1201.	......	......	......
Average........	.....	738.	52.5	270	769.5	9987.5	1505.0	798.5	97.6	6	80
Linna	08–09	558.	....	350	1336.7	8302.7	2048.5	132.5	......	......	80
"	09–10	965.	215.	170	96.0	8547.0	877.0	835.0	......	......	......
Average........	.....	761.5	107.5	260	716.3	8424.8	1462.7	483.7	......	......	40
Millie...............	08–09	588.	....	350	1336.0	7384.	1984.2	434.	112.8	9	150
Bess...............	09–10	833.	215.	120	185.0	7277.	875.	840.	......	......	......
Lena...............	08–09	552.	....	350	1331.	9508.	2106.8	512.	195.2	12	150
"	09–10	693.	215.	342	115.	7161.	822.	872.	......	......	......
Average........	.....	622.5	107.5	346	723.	8334.5	1464.4	642.	97.6	6	75

Table IV. — Feed Consumed per Cow per Year, 1908--1910. — Cont.

Name of Cow	Year	Timot'y Hay	Clover Hay	Prairie Hay	Millet Hay	Silage	Bran	Shorts	Bar-ley	Oats	Corn	O.M
Daisy 2nd	09–10	728.	210.	170	185.	5808.	867.	945.	......	......	......	....
Zizos Lady	09–10	823.	80.	170	185.0	5020.	849.5	928.	......	......	......	....
Gem's Brown Bessie	09–10	728.	215.	197	185.0	4260.	640.	549.5	......	......	......	....
Tibby	09–10	560.	215.	197	185.0	4548.	820.	867.0	......	......	......	....
Nettie 2nd	09–10	583.	45.	170	185.	5148.	780.	858.	......	......	......	....
Vina 3rd	09–10	443.	45.	170	185.	3504.	717.	683.	......	......	......	....
Madison Miss Ormsby	09–10	303.	215.	170	98.	3353.	258.5	304.5	......	157.	162.	Al-falfa 23.0
Lucy 2nd	08–09	594.0	....	350	1331.0	8918.0	1900.4	368.0	195.2	12.	94.	....
" "	09–10	443.0	115.0	170	226.0	4386.0	1064.0	416.0	128.0	12.	......	....
Average	.....	518.5	57.5	260	778.5	6652.0	1482.2	392.0	161.6	12.	47.	
Gem 3rd	08–09	168.0	....	280	1300.0	6424.0	1836.0	154.0	......	......	10.	....
Clara 2nd	08–09	594.0	....	350	1331.0	8828.0	2107.0	270.0	195.2	12.	150.	....
" "	09–10	555.0	225.0	170	185.0	5062.0	1234.5	207.5	......	......	......	....
Average	.....	574.5	112.5	260	708.0	6945.0	1670.7	238.7	97.6	6.	75.	

THE VARIATION SHOWN IN THE RECORDS OF THE COWS DURING THE CALENDAR YEAR PERIODS

The summary table which gives the production and net profit produced by the cows during the years 1908 and 1909 shows that the cows vary considerably in the net profits they produced. Goldies Wilda has the largest net profit to her credit, $67.90, while Millie, the cow with the lowest net profit only shows an average profit of $20.47, or a difference of $47.43. A study of the profits credited to the other cows that were in the herd shows a great range of variation in their productive capacities and economy of production. It is readily determined, which cows should be kept in the herd and which ones should be culled out. In fact this can be ascertained with a considerable degree of accuracy from the amount of butter fat credited to each cow. To be sure the most accurate method is to have record of the feed consumed, for it can be seen from the summary table of production that some cows with a smaller amount of butter to their credit show a greater net profit than some with more butter to their credit. Nevertheless it is to be seen that a knowledge of the amount of milk and fat a cow produces would afford the dairyman quite a satisfactory means for determining the comparative value of his cows in the herd, or in other words, which are the boarders in the herd, and which are the profit makers. It is very necessary that every dairyman should keep a record of the milk produced by every cow in the herd and test their milk for butter fat at least once a month, so as to be able to determine how much butter fat each cow is producing, which can be used as a basis for selecting a herd of economic producers. It is essential to know what per cent of fat each cow's milk contains, for the value of a cow can not be judged from the amount of milk she produces, considering milk is sold almost exclusively at present on the basis of the fat it contains. For example, Princess Teake, whose average milk production is given in the summary table as 8,211.8 pounds, has less fat to her credit than Lucy 2d that has only 4,716.4 pounds of milk to her credit. The one has an average test of 2.9 per cent. and the other a test of 5.6 per cent., which accounts for the difference.

Table V. — The Average of the Results Produced by the Herd Each Year 1904–1910 inclusive

Year	No. of Cows	Milk Pounds	Ave. Test	Fat Produced	Butter Produced	Value of product	Cost of Feed	Net Profit	Cost of Fat per lb.
Jan 1–Jan 1				Lbs.	Lbs.	$	$	$	Cts.
1904–1905	6	6607.9	.....	....	....	....	....	....	....
1905–1906	6	5499.9	.....	....	....	....	....	....	....
1906–1907	8	4708.1	.....	....	....	....	....	....	....
1907–1908	10	4692.2	.....	....	....	....	....	....	....
1908–1909	9	5618.0	.....	225.6	262.0	85.73	41.53	44.19	18.4
1909–1910	14	4469.8	.....	188.0	219.8	72.19	26.20	45.34	13.9
Average.	....	5265.9	.....	206.8	240.9	78.96	33.86	44.76	16.1

DIFFERENCE IN THE MILKING PERIODS

In comparing the number of days the cows were in milk as recorded in the table of annual production of the cow's page, it is to be observed that some cows have milked more days during the year, some years, than others. As a rule their lowest production is during the year of short milking period. From these facts it is evident that it is important not to have the cows dry for too long a period each year, or it will decrease perceptibly the profit the cows will produce annually. A cow should not be dry to exceed six or seven weeks each year. It should be the aim to breed the cows so they will calve every 12 or 13 months. This will allow them to milk a period of 11 or 12 months before they are dried up. It requires considerable vigilance to get the cows bred so they will calve at the desired time, especially if the cows do not conceive readily.

COMPARISON OF THE RESULTS FOR THE YEARS 1908 AND 1909

A comparison of the average amount of butter, cost of feed consumed and net profit per head of the cows in the herd for 1908 and 1909 is given in the table above. They produced 262 pounds of butter per head in 1908 and 219.8 pounds in 1909, and made a net profit of $44.19 in 1908 and $45.34 in 1909. The difference in the net profit differed little because of the low cost of the feed consumed per head in 1909. The wide difference in the cost of the feed consumed by the cows in 1908 and 1909 is rather remarkable, but it is to be accounted for, by the fact that the cows milked a less number of days in 1909 and by the fact that the cows were not as liberally fed during 1909. They were not fed as much silage or hay in particular and they were not fed as heavy a grain ration. This may account in part for the lower yield made by the herd in 1909. The difference in yield may also be due partially to the fact that there were fourteen cows included in the average for 1909 and only nine for 1908, and some of the additional cows in the herd in 1909 were inferior producers compared with the cows in milk in 1908.

COST OF PRODUCING BUTTER FAT

In the table, page 152, which gives the average of the results produced by the whole herd for each year, the cost of producing butter fat per pound is given. The average for 1908 and 1909 is 16.1 cents a pound. It is to be remembered that the cost of the labor in caring for the cows and the interest upon the cost of the cows was not charged against them in deriving the cost of production. Only the cost of the feed is included in the cost of production. The value of the manure is taken as offsetting the cost of labor, as it is customary to do in preparing estimates of this kind. If the cows were credited with the value of the manure it would, no doubt, offset the cost of the labor required to care for the herd. The cost of the butter fat as determined indicates that it was produced economically and that there is a good margin of profit in producing butter fat for our farmers who will undertake it, providing they have good cows and give them the proper care.

THE RECORDS OF THE HERD DURING THE LACTATION PERIODS

The following tables give the record of milk produced by the cows in the herd figured on the basis of the lactation period from 1904-1910, and of the butter fat and feed consumed in addition for the past two years. As stated before, this makes it possible to determine the relative capacity of the cows as producers for a yearly period at least, with greater accuracy. The net profit of a year's production figured on this basis, shows the profit made for the actual time the cow is in milk and no allowance is made for the cost of the keep of the cow when not milking.

Table VI. — Production of Cows in Herd Lactation Periods 1904--1910.

Name of Cow	Date of Freshening	Days in Milk	Pounds of Milk	Fat %	Fat lbs.	Butter	Value of Product	Cost of Feed	Net Profit
Goldies Wilda	Feb. 18, 1904	346.	7367.3	......	......	......	......	......	......
" "	Mar. 30, 1905	365	8176.3	......	......	......	......	......	......
" "	Sept. 11, 1906	365	7442.2	......	......	......	......	......	......
" "	Jan. 9, 1908	365	6899.4	4.15	288.7	336.8	$112.08	$44.08	$68.00
Average........	....	360.	7471.3						
Vina...............	Feb. 4, 1904	365	11796.8	......	......	......	......	......	......
"	Aug. 20, 1905	365	12793.6	......	......	......	......	......	......
Average........	....	365	12295.2						
Lucy...............	Apr. 7, 1904	314	9907.4	......	......	......	......	......	......
"	May 12, 1905	365	8135.8	......	......	......	......	......	......
"	Nov. 3, 1907	365	4677.7	3.9	182.5	212.9	$71.35	$46.26	$25.09
Average........	....	....	7573.6						
Recorder's Gem......	Feb. 18, 1904	362	5413.3	......	......	......	......	......	......
" "	May 18, 1905	365	4702.0	......	......	......	......	......	......
" "	Oct. 25, 1907	365	4800.7	5.1	248.0	289.3	$94.48	$43.61	$50.87
" "	Feb. 20, 1909	365	4241.8	5.0	222.1	259.1	$84.51	$29.54	$54.97
Average........	....	....	4789.4	......	235.0	274.2	$89.49	$36.57	$52.92

Table VI. — Production of Cows in Herd Lactation Periods 1904--1910.—Cont.

Name of Cow	Date of Freshening	Days in Milk	Pounds of Milk	Fat %	Fat lbs.	Butter	Value of Product	Cost of Feed	Net Profit
Princess Teake......	Mar. 13, 1907	365	10047.7	......	......	......	......	......	......
" "	July 14, 1908	365	10621.9	2.8	324.7	378.8	$131.55	$46.79	$84.76
Average.......	....	....	10334.8						
Sunstroke...........	Oct. 18, 1904	239	3188.5	......	......	......	......	......	......
Daisy...............	Feb. 25, 1904	334	5043.8	......	......	......	......	......	......
"	July 30, 1907	273	4048.9	4.48	181.56	211.8	$70.02	$34.95	$35.07
Average.......	....	....	4546.3						
Miss Sunstroke......	June 21, 1909	365	4184.7	5.10	214.8	250.5	$81.77	$26.29	$55.48
Vina 3rd............	July 16, 1908	365	3969.6	3.90	155.6	181.5	$60.79	$32.29	$28.50
Madison Miss Ormsby	Mar. 10, 1909	365	6666.1	3.40	226.8	264.8	$90.10	$25.72	$64.38
Nettie 2nd..........	Nov. 2, 1908	331	3328.9	4.19	139.7	163.3	$54.31	$28.60	$25.71
Lucy 2nd...........	May 2, 1906	365	3720.6	......	......	......	......	......	......
" "	July 23, 1907	365	4850.5	5.18	251.5	293.4	$95.74	$41.89	$53.85
" "	July 23, 1908	365	5314.8	5.06	268.4	313.1	$102.43	$37.32	$65.11
Average.......	....	365	4471.5	......	259.9	303.2	$99.08	$39.65	$59.44

Table VI. — Production of Cows in Herd Lactation Periods 1904--1910.—Cont.

Name of Cow	Date of Freshening	Days in Milk	Pounds of Milk	Fat %	Fat lbs.	Butter	Value of Product	Cost of Feed	Net Profit
Gem 3rd............	Mar. 28, 1906	365	3892.7	......	....	....	....	....	....
" "	June 12, 1907	365	4578.3	4.14	189.3	220.8	$73.57	$41.82	$31.75
Average........	....	365	4235.5						
Clara 2nd...........	May 2, 1906	363	3833.6	......	....	....	....	....	....
" "	June 19, 1907	365	6556.6	4.50	298.8	348.6	$115.07	$42.35	$72.72
" "	June 19, 1908	364	5273.4	5.00	263.8	307.7	$100.07	$36.05	$74.02
Average........	....	......	5221.2	......	281.3	328.1	$107.57	$39.20	$73.37
Linna	May 18, 1905	341	4653.1	......	....	....	....	....	....
"	May 21, 1906	339	4069.7	......	....	....	....	....	....
"	July 29, 1907	365	5306.2	3.31	187.8	219.1	$74.22	$40.48	$33.74
"	Apr. 13, 1909	330	5829.6	3.65	213.1	248.6	$83.90	$29.07	$54.83
Average........	....	343.	4964.4	......	200.4	233.8	$79.06	$34.78	$44.29
Millie...............	May 21, 1907	365	4153.6	......	....	....	....	....	....
"	May 23, 1908	365	3361.3	6.50	221.69	258.6	$82.96	$36.07	$46.89
Average........	....	365	3757.4						
Bess................	May 27, 1908	365	6746.2	3.82	258.3	301.0	$101.13	$42.81	$58.32
"	Aug. 2, 1909	365	5887.1	4.08	240.6	280.7	$93.62	$35.99	$57.63
Average........	....	365	6325.6	......	249.4	290.8	$97.37	$39.40	$57.97

Table VI. — Production of Cows in Herd Lactation Periods 1904--1910.—Cont.

Name of Cow	Date of Freshening	Days in Milk	Pounds of Milk	Fat %	Fat lbs.	Butter	Value of Product	Cost of Feed	Net Profit
Lena	Sept. 18, 1906	365	8076.6	......	......	......	......	......	......
"	Nov. 26, 1907	365	8942.3	2.98	266.7	311.1	$109.64	$44.21	$65.43
"	July 11, 1909	365	7140.0	3.28	234.5	273.5	$93.47	$35.61	$57.86
Average	......	365	8052.9	......	250.6	292.3	$101.55	$39.91	$61.64
Daisy 2nd	Aug. 24, 1908	365	5016.0	4.57	229.7	268.0	$78.42	$32.10	$46.32
Zizo's Lady	Aug. 31, 1908	365	5028.5	3.80	191.3	223.2	$75.00	$31.40	$43.60
School Girl	Dec. 17, 1906	323	5364.7	......	......	......	......	......	......
Pet	Apr. 24, 1904	365	7494.3	......	......	......	......	......	......
Gem's Brown Bessie	July 27, 1908	275	1608.7	7.47	120.2	140.2	$44.63	$25.95	$18.68
" " "	Aug. 9, 1909	303	2042.7	7.46	152.4	177.8	$59.00	$22.66	$36.36
Average	......	289	1825.7	......	136.3	159.0	$51.81	$24.31	$27.52
Tibby	Dec. 12, 1908	365	5984.8	4.58	274.2	319.9	$105.54	$29.52	$76.02

Table VII. — Summary of Production of the Herd Lactation Periods 1904--1910

Name of Cow	Breed	No. of Yrs.	Live Wgt.	Days in Milk during Year	Milk	Production			Value of Product	Net Profit
						Fat	Fat	Butter		
			lbs.		lbs.	%	lbs.	lbs.	$	$
Princess Teake	H.	1	1430	365	11196.1	2.90	324.7	378.8	131.55	84.76
Tibby	Gr. J.	1	802	365	5984.8	4.58	274.2	319.9	105.54	76.02
Clara 2nd	Gr. J.	2	962	365	5915.0	4.75	281.3	328.1	107.57	73.37
Goldies Wilda	J.	1	852	365	6899.4	4.19	288.7	336.8	112.08	68.00
Madison Miss Ormsby	H.	1	800	365	6666.1	3.40	266.8	264.8	90.10	64.38
Lena	Gr. H.	2	1103	365	8041.1	3.11	250.6	292.3	101.55	61.64
Lucy 2nd	Gr. J.	2	892	365	5082.6	5.11	259.9	303.2	99.08	59.44
Bess	Gr. H.	2	960	365	6325.6	3.94	249.4	290.8	97.37	57.97
Miss Sunstroke	R. P.	1	900	365	4184.7	5.13	214.8	250.5	81.77	55.48
Recorder's Gem	J.	2	672	365	4521.2	5.19	235.0	274.1	89.49	52.92
Millie	Gr. J.	1	760	365	3361.3	6.59	221.7	258.6	82.96	46.89
Daisy 2nd	Gr. J.	1	695	365	5016.0	4.57	229.7	268.0	78.42	46.32
Linna	R. P.	2	980	347	5567.9	3.60	200.4	233.8	79.06	44.29
Zizo's Lady	R. P.	1	767	365	5028.5	3.80	191.3	223.2	75.00	43.60
Daisy	Gr. J.	1	1130	273	4048.9	4.51	181.6	211.8	70.02	35.07
Gem 3rd	Gr. J.	1	860	365	4578.3	4.13	189.3	220.8	73.57	31.75
Vina 3rd	Gr. J.	1	760	365	3969.6	3.92	155.6	181.5	60.79	28.50
Gem's Brown Bessie	J.	2	782	289	1825.7	7.46	136.3	159.0	51.81	27.52
Nettie 2nd	Gr. J.	1	670	331	3328.9	4.19	139.7	163.3	54.31	25.71
Lucy	Gr. H.	1	1062	365	4677.7	3.90	182.5	212.9	71.35	25.09

Table VIII. — Feed Consumed by the Cows in the Herd During Lactation Periods 1908--1910

Name of Cow	Date of Freshening	Timot'y Hay	Clover Hay	Prairie Hay	Millet Hay	Silage	Bran	Shorts	Bar-ley	Oats	Corn	Oil Meal
Goldie's Wilda	Jan. 9, 08	648.0	....	140.0	1331.0	8858.0	2016.8	464.0	195.2	12.0	192.0	.....
Lucy..........	Nov. 3, 07	252.0	....	840.0	1709.0	9468.0	2084.2	510.0	89.6	......	150.0	.....
Recorders Gem	Oct. 25, 07	234.0	....	910.0	1290.0	7653.6	2103.6	524.0	62.0	12.0	150.0	.....
" "	Feb. 20, 09	1035.0	215.0	170.0	185.0	5226.0	858.5	891.5	......	......	......	.....
Average...	....	634.5	107.5	540.0	737.5	6439.8	1481.0	707.7	31.0	6.0	75.0	
Princess Teake	July 14, 08	1183.0	....	204.0	211.0	10552.0	1708.8	1166.0	195.2	12.0	98.0	.....
Daisy.........	July 30, 07	....	....	980.0	910.0	8134.0	1464.0	530.0	......	......	......	.....
Miss Sunstroke	June 21, 09	811.0	215.0	....	205.0	5412.0	1463.0	63.0	......	......	......	.....
Vina 3rd......	July 16, 08	1031.0	....	170.0	191.0	5580.0	1173.4	648.0	192.6	9.0	113.0	.....
Madison Miss Ormsby.....	Mar. 19, 09	617.0	215.0	170.0	198.0	5369.0	412.5	651.5	157.0	162.0	78.0	.....
Nettie 2nd.....	Nov. 2, 08	773.0	45.0	170.0	191.0	4848.0	892.6	865.0	......	......	......	.....
Lucy 2nd......	July 23, 07	....	....	980.0	1290.0	9077.0	1757.0	888.0	......	......	10.0	.....
	....	420.0	....	280.0	1331.0	8598.0	1956.0	336.0	128.0	12.0	94.0	67.2
Average...	....	210.0	....	630.0	1310.5	8837.5	1856.5	612.0	64.0	6.0	52.0	33.6
Gem 3rd......	June 12, 07	....	....	910.0	1290.0	8417.0	1728.0	898.0	......	......	26.0	.....
Clara 2nd.....	June 19, 07	....	....	980.0	1290.0	9597.0	1049.0	661.0	......	......	......	.....
" "	June 19, 08	991.0	....	170.0	226.0	6816.0	1645.3	431.0	195.2	12.0	150.0	.....
Average...	....	495.5	....	575.0	758.0	8206.5	1747.1	546.0	97.6	6.0	75.0	

Table VIII. — Feed Consumed by the Cows in the Herd During Lactation Periods 1908--1910 — Cont.

Name of Cow	Date of Freshening	Timot'y Hay	Clover Hay	Prairie Hay	Millet Hay	Silage	Bran	Shorts	Bar-ley	Oats	Corn	Oil Meal
Linna B.......	July 27, 07	....	....	980.0	1290.0	9217.0	1982.0	481.0	......	......	250.0	.....
" ".......	Apr. 13, 09	635.0	215.0	170.0	30.0	5214.0	1176.0	750.0	......	......	......	.....
Average...	....	317.5	107.5	575.0	660.0	7215.5	1579.0	615.5	......	......	125.0	.....
Millie.........	May 23, 08	991.0	....	170.0	436.0	6504.0	1670.0	453.2	112.8	9	150.0	.....
Bess..........	May 27, 08	1031.0	....	30.0	576.0	8300.0	1810.0	729.0	195.2	......	98.0	.....
"	Aug. 2, 09	955.0	240.0	120.0	105.0	8435.0	1092.0	1092.0	......	......	......	49.0
Average...	....	496.5	120.0	75.0	340.5	8367.5	1451.0	910.5	87.6	......	49.0	24.5
Lena..........	Nov. 26, 07	366.0	....	719.0	1341.0	7538.0	2122.0	463.2	176.0	12.0	150.0	.....
"	July 11, 09	885.0	265.0	....	205.0	8145.0	1098.0	1098.0	......	......	......	35.0
Average...	July 11, 09	625.5	132.5	359.5	773.0	7841.5	1610.0	780.6	188.0	6.0	7.5	17.5
Daisy 2nd.....	Aug. 24, 08	1031.0	....	170.0	216.0	5756.0	1077.0	795.0	164.4	9.0	33.0	.....
Zizo's Lady....	Aug. 31, 08	1031.0	80.0	170.0	226.0	4644.0	1065.9	837.0	134.4	9.0	22.0	.....
Gem's Brown Bessie.......	July 27, 08	1031.0	....	35.0	226.0	4076.0	974.6	354.0	135.6	9.0	88.0	.....
Gem's B. Bessie	Aug. 9, 09	810.0	215.0	....	215.0	5350.0	574.0	574.0	......	......	......	.....
Average...	....	920.5	107.5	17.5	220.5	4713.0	774.3	464.0	67.8	4.5	44.0	
Tibby.........	Dec. 12, 08	742.0	215.0	170.0	185.0	5220.0	899.0	977.0	......	......	......	.....

COMPARISON OF RECORDS

A comparison of the yearly records made by the cows during the lactation periods with those for the calendar year shows that the records made during the lactation period is considerably larger. This, of course, is accounted for by the fact that the cows milked each day during their lactation periods and were dry for some time during the calendar year.

Some of the cows made creditable production records during their lactation periods. Princess Teake is at the head of the list of producers having made 378.8 pounds of butter during a single lactation period, at a net profit of $84.76. Goldies Wilda has the next highest butter record which is 336.8 pounds. Goldies Wilda, however, does not show as great a net profit as Tibby and Clara 2d, that produced 319.9 pounds and 328.1 pounds (average for two years) respectively. Gems Brown Bessie has the lowest butter record of 159.0 but shows a greater net profit than Lucy which has the lowest net profit of all the cows. This low record made by Lucy from November 3d, 1907, to November 3d, 1908, is to be accounted for by the fact that she lost the use of one quarter of her udder at freshening time. Lucy was one of the best cows in the herd previous to the year just mentioned, as a comparison of her milk yield in the preceding lactatiŏn periods will indicate. She was dropped from the herd after she completed the year of last record.

Gems Brown Bessie has a very high fat test which the summary table shows to be 7.46 for the average of two lactation periods; but she gives a very small quantity of milk which accounts for the low yield of total butter fat.

Table IX. — Comparison of the Average Production of the Breeds in the Herd.

Breeds	No. of Cows	Milk	Fat	Fat	Butter	Value of Products	Net Profit
		Lbs.	Per ct	Lbs.	Lbs.		
Holsteins	2	8931.1	3.15	295.7	321.8	$110.83	$74.57
Grade Holsteins	3	6348.1	3.65	227.5	265.3	90.90	48.23
Jerseys	3	4415.4	5.61	220.3	256.6	84.46	49.44
Grade Jerseys	9	4509.5	4.60	214.7	251.7	81.37	47.0
Red Polls	3	4927.0	4.00	202.2	235.8	78.61	47.7

COMPARISON OF THE RECORDS BY BREEDS

The records made by the cows of each breed were averaged for the purpose of comparison in the table which precedes. The table shows the average results produced by the Holsteins, grade Holsteins, Jerseys, grade Jerseys, and Red Polls. The results of this comparison is of no value for the purpose of determining the relative merits of the breeds represented, on account of the number of cows of each breed represented being too small to warrant drawing such conclusion. With such a small number there is the danger that the cows of one breed may be better representatives of the breed than the cows of another breed. It is possible, however, to get a rather accurate knowledge of the difference in the fat test of the different breeds. From this table it will be seen that the Holsteins have the lowest test of 3.15 per cent., the Grade Holstein stand next lowest, with a test of 3.65. The Jerseys have the highest fat test which is 5.61 per cent. and the grade Jerseys the next highest with 4.6 per cent., while the Red Polls have an average fat test of 4 per cent.

We may also be justified in making a comparison of the net profit produced by the pure breds compared with the grades. The pure breds have excelled the grades except in the case of the Red Polls which are excelled slightly by the grade Jerseys. This demonstrates the superiority of well bred cows over grades or scrubs, and demonstrates the advisability of using high grades or pure breds in preferencce to scrubs or cattle of no particular breeding.

Table X. — Average Daily Feed Consumed and Products Produced Daily by the Herd, Lactation Periods 1908--1910

Name of Cow	Feed Consumed								Products		
	Avg. Days in Milk	Hay	Silage	Bran	Shorts	Oats Barley Corn	Oil Meal	Total Grain	Milk	Fat	Avg. Wt.
		Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Princess Teake..........	365	6.8	41.70	4.6	3.2	B .530 C .270 O .030	.....	8.63	30.6	.90	1430
Tibby.................	365	5.4	21.82	2.4	2.4	....	.....	4.80	16.4	.75	802
Clara 2nd............	365	6.7	31.80	4.7	1.5	O .170 C .200	.....	6.417	14.2	.77	902
Goldie's Wilda..........	365	8.7	35.01	5.5	1.2	B .530 O .270 C .500	.....	7.700	18.9	.79	852
Madison Miss Ormsby...	365	4.8	13.86	1.1	1.7	O .400 C .420 B .240	.21	3.830	18.2	.73	800
Lena.................	365	8.0	32.13	4.4	2.1	C .017 O .200	.07	6.957	22.0	.68	1130
Lucy 2nd..............	365	9.1	34.21	4.8	1.5	O .017 C .140	.09	6.547	13.9	.71	892
Bess..................	365	6.2	35.00	3.9	2.4	C .130	.06	6.490	17.3	.68	960
Miss Sunstroke.........	365	4.9	24.05	4.0	.1	....	.....	4.100	11.4	.59	900
Recorder's Gem.........	365	8.5	26.39	4.0	1.9	B .100 O .017 C .200	.....	6.217	12.3	.64	672
Millie..................	365	6.6	21.76	4.5	1.2	C .400 O .024 B .300	.....	6.424	9.2	.60	760

Table X. — Average Daily Feed Consumed by the Herd, and Products Produced Daily, Lactation Periods 1908--1910.—Cont.

Name of Cow	Feed Consumed								Products		
	Avg. Days in Milk	Hay	Silage	Bran	Shorts	Oats Barley Corn	Oil Meal	Total Grain	Milk	Fat	Avg. Wt.
		Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Daisy 2nd.............	365	5.9	22.70	3.9	2.1	B .460 O .024 C .090	.....	6.574	13.7	.63	695
Linna	347	7.0	29.90	4.5	1.8	C .300	.....	6.600	16.0	.57	980
Zizo's Lady............	365	6.2	18.38	3.9	2.3	B .360 O .024 C .016	.....	6.300	13.7	.52	767
Daisy.................	273	8.4	30.92	5.3	1.7	C .350	.....	7.350	13.8	.66	1130
Gem 3rd...............	365	9.7	32.00	4.7	2.4	B .170 O .030 C .090	.....	7.390	12.5	.51	860
Vina 3rd..............	365	5.7	22.05	3.2	1.7	B .520 O .024 C .280	.....	5.740	10.8	.42	760
Gem's Brown Bessie....	289	5.1	19.98	2.5	1.6	B .180 O .012 C .200	.....	5.690	6.3	.47	782
Nettie................	331	4.9	19.10	2.6	2.6	....	.....	5.200	10.0	.42	670
Lucy..................	365	12.4	36.00	5.7	1.4	B .200 O .024 C .410	.....	7.730	12.9	.50	1062
Average..........	....	7.12	27.42	4.01	1.84	.443	.021	6.334	14.7	.624	917.6

RELATION OF DAILY FEED CONSUMED TO DAILY FAT PRODUCED BY HERD

The tables just preceding give a record of the feed consumed by the cows in the herd during their lactation periods since 1907. The average of the cows have completed two lactation periods. It is to be observed that many have only one lactation period to their credit, that is because some of them have only been in the herd during the last year and others were dropped from the herd during the last year. The average daily amount of roughage and grain consumed by each cow is given in a separate table and furnishes interesting data. Where the cows completed two lactation periods, an average was taken of the two periods. The hay and silage fed is computed for the actual days they were fed these feeds, during the year, and the grain is an average of the daily amount fed during the number of days the cows were in milk or for the total lactation period.

It will be seen that the heavy cows consumed a larger quantity of feed daily than the small cows, and the amount of butter fat they produced daily was correspondingly larger. The average of the daily ration of the whole herd for the two years, per head, was as follows: Hay 7.12 pounds, Silage 27.42 pounds, Grain 6.33 pounds. The average amount of milk and fat produced daily by the herd was as follows: Milk 14.70 pounds, fat .624 pounds. The average amount of grain fed daily per head was one pound for every .68 pounds of fat produced per week.

THE NUTRITIVE RATIO OF THE AVERAGE DAILY RATION FED

The digestible nutrients and the nutritive ratio of the average daily ration fed the cows of the herd for the two years of the lactation period, was determined. This was calculated from the digestible nutrients of the feeds fed as given in Henry's Feeds and Feeding. Samples of the feed fed during the period of these records were not analyzed so that the digestible nutrients in the ration as determined from the tables that we used will only be approximately correct.

The silage that we have no doubt differs considerably from the average silage made in the Central States from which the analysis given in the standard tables was made. The figures given for the digestible nutrients in mixed hay was used for computing the digestible nutrients in the hay of the ration. These figures will come very close to representing the grade of the hay fed. The digestible nutrients derived in the method described will not be far from representing actual nutrients, the only room for a large difference would be in the analysis of the silage.

Table XI. — Digestible Nutriments in the Average Daily Ration Fed the Herd During Lactation Periods 1908--1909

Kind of Feed	Amount	Dry Matter	Protein	Carbohydrates	Ether Extract	Nutr. Ratio
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Hay..............	7.12	6.20	.420	2.91	.085	....
Silage............	27.42	5.90	.280	3.52	.218	....
Bran..............	4.01	3.53	.489	1.57	.108	....
Shorts............	1.84	1.62	.224	.94	.071	....
Oats..............	.443	.39	.040	.21	.018	....
Oil Meal..........	.021	.02	.006	.01	.002	....
		17.66	1.459	9.16	.502	1:7.1
Haecker's Standard	....	....	1.330	9.80	.355	1:7.9

The table above shows that the digestible nutrients in the average ration fed are as follows: 17.66 pounds dry matter, 1.46 pounds digestible protein, 9.80 pounds digestible carbohydrates and .355 pounds digestible ether extract. It is also to be observed that the ration compares quite closely to the standard recommended by Haecker, of the Minnesota station, for a cow of the same weight as the cows in our herd averaged and producing 14.7 pounds of milk daily testing an average of 4.2 per cent. It is evident that the average ration fed the cows in our herd for the past two years has been very close to the correct requirements for the largest and most economical production of milk and butter fat.

The nutritive ratio of the ration is 1:7.1 and while it might be considered a little wide for some sections of the country considering the market price of feeds with the cheap price which roughage commands on our farms and markets a wide ration is almost sure to be the economical one.

SUMMARY

1. The results obtained with the herd as recorded in this bulletin indicate that milk production can be successfully carried on under North Dakota conditions providing the cows are well sheltered during the winter months and well fed and managed throughout the year.

2. The results of the data given in this bulletin also show that the special purpose dairy breeds prove profitable under the climatic conditions of this state if given reasonably good care.

3. The cost of producing butter fat with the Station herd for the period of two years for which the cost was determined demonstrated that butter fat was produced economically compared with the cost of producing it in other states.

4. The cost of the rations fed in this trial indicate that the results obtained and the relative cheapness of all roughage on the farms of this state make a ration with a wide nutritive ratio more profitable to feed a dairy cow than one higher in protein or narrower.

5. A comparison of the relation between feed consumed and butter fat produced by the cows in the herd demonstrates that they must be fed in proportion to the amount of milk yield in order to produce economically. The records of the cows in the herd show that the large producers consumed more feed than the lighter milkers and that if the small producers had not been fed in proportion to their production they would not have shown a profit.

6. The trial also shows that the individual peculiarities of the different cows must be taken into account in making up a ration for them both in the nutritive ratio and in the total quantity of feed given. As pointed out in the body of the bulletin some of the cows in this trial required protein food to prevent undue fleshing and a reduction of milk flow.

Other cows in the experiment which had a natural tendency toward dairy production consumed a larger proportion of the starchy feed (a narrower ration) without fleshing up at the expense of milk production. The trial suggests also that there may be a decided choice in the physical type of the protein carrying grain fed to the cow. Further study on this point should be carried out.

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EXPERIMENT STATION
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Bulletin No. 92

PAINTS: THEIR SERVICE CONDITION

BY

E. F. Ladd and E. E. Ware

Any farmer, teacher, or student in the State may have this Bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
June, 1911

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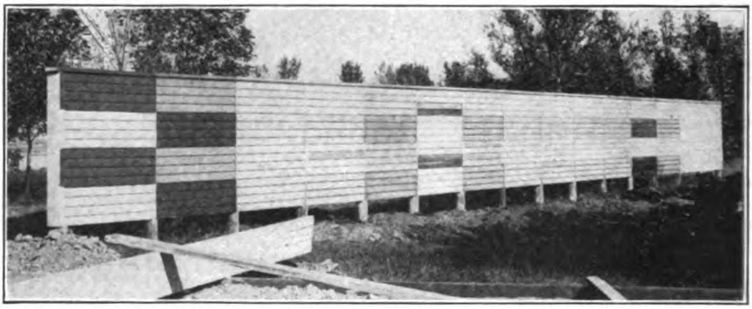

(Original test fence built in 1906, east side before repainting in 1910)

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PAINTS: THEIR SERVICE CONDITION

By E. F. Ladd and E. E. Ware

INTRODUCTION

The first extensive paint experiments undertaken at the College were begun in 1906, when there was erected the first paint test fence of 15 sections, known as the original test fence. On this fence there were applied several commercial paints representing several types, including some of the well-known catalog-house paints and white leads. The purpose of these experiments was to secure data which would enable us to judge something of the practical value of the paints and whether the analysis of a paint would indicate anything of the value of the paint for the purposes for which paints are to be used.

Since then a large number of additional experiments have been undertaken, and there have been erected four additional test fences, each much larger than the original. In addition to these fences, fourteen buildings, including residences and public buildings, have been painted, some for the first time and in other cases the buildings have been re-painted. Paints which have been tested upon the experimental fences have also been used upon buildings, in order that data might be secured under both conditions. The fence tests show a more accelerated wearing for the paints than where the paints were used upon houses. Nevertheless, the conditions are identical throughout on the fences and thus give results much more comparable for different paints and different types of lumber, than would be the case upon buildings where the conditions varied in each individual case, even for the side of the building under test.

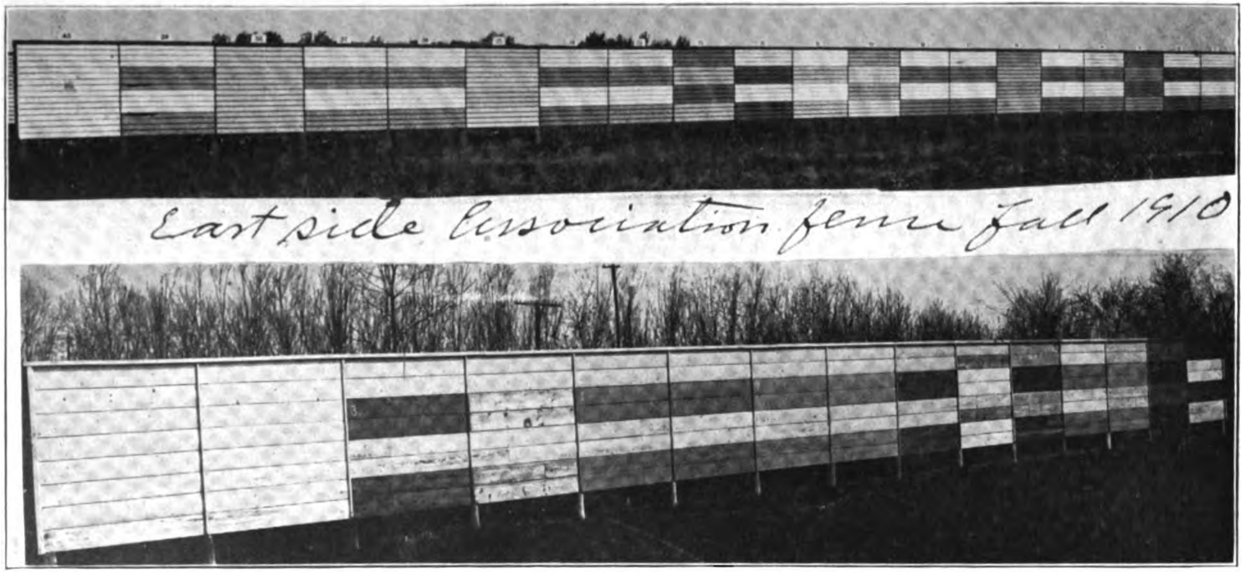
The construction of the fences is well shown in the cut. The fences have been fully described in previous bulletins from this Department, particularly No. 81. Two types of clapboards are used on one side of the fence, namely soft pine and cedar. On the other side of the fence, as shown in the illustration, boards of two types are used, one soft pine and the other Minnesota Hard Pitch Pine. This has furnished a splendid opportunity for a comparison of the relative value of paints upon different types of lumber where the paints are all put on under the same general conditions.

The work on these fences was undertaken in co-operation with the Paint Manufacturers' Association of the United States, and for the original painting they furnished a representative who was present and took part in the work, also in connection with a representative of the National Lead Company, who was present and aided in the reduction of the white leads and their application.

It is not our purpose, at this time, to draw general conclusions with regard to the relative value of the several paints. Experience has taught us that often a paint which wears well does not necessarily form a good basis for repainting; that the second paint, while apparently unsatisfactory in its wearing qualities, may have its source of trouble in the original paint. It is, therefore, necessary before drawing general conclusions to have the work repeated in the re-painting of the several tests as first made.

Each year additional experiments have been carried on, and at the present time it is proposed to continue these experiments for a series of years, extending the number of the tests so as to cover fields not yet touched upon. In this connection the Department has purchased a complete experimental paint plant for the manufacture of its own paints for certain lines of experimental work.

In going over the results, as presented in this bulletin, the data presented is for the conditions as found at the time of making the inspection in the fall of 1910. For convenience, the paints have been grouped in classes of like composition and properties, so as to make possible a better study



Shows West Side Construction of one of Test Fences Before Repainting

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for those who may be interested in going over the data. Each may draw his own conclusions from the data as presented.

The characteristics of the different types of paints are in some cases quite marked, as are the conditions of checking, peeling, scaling, etc. The data presented shows also the general harmful effects of the presence of water in paints; the effect of applying paints where the lumber is not thoroughly dry; and to some extent there are experiments showing the relative value of other oils used in part or whole for linseed oil. There are certain experiments showing the value of substitutes for turpentine. It may be said that the use of a small quantity of turpentine has generally proved beneficial, while the addition of a large amount of turpentine has brought about conditions unsatisfactory as shown in the wearing quality of the paint.

For the present year particular attention is to be given to the question of substitutes for linseed oil and substitutes for turpentine. The results of these experiments will form the basis of future reports from this Department.

1911 REPORT OF TEST FENCES AND HOUSES

In compiling this report on conditions of test fences painted in 1906, 1907, 1908 and test houses painted in 1907, 1908, 1909, an endeavor has been made to so group the results as to bring together paints of similar type, thus to facilitate the comparison of such similar types under varying conditions, as well as to show the action of differing types under identical conditions of exposure.

The report will follow the same general lines as have the previous reports put out by the Department, except that no formulæ will be given, each test being referred to simply by number, the formulæ corresponding to these numbers being given in full in Station Bulletin 81, Paint Bulletin No. 2, or Paint Bulletin No. 4.

The descriptive terms employed will be the same as used in previous reports; but, inasmuch as the clear interpretation of the results necessarily depends largely upon the reader's understanding of such terms as may have been used, it has seemed advisable to insert at this point, definitions of the terms as used, with illustrations showing how they have been applied to conditions existing on the test fences and houses.

GENERAL CONDITION

Summarizes the conditions observed in the test, the general appearance, wear, and characteristic disintegration of the paint surface.

CONDITION FOR RE-PAINTING

This important factor runs parallel in most cases to the general condition of the paint surface. The requirements here being almost entirely modified by the surface of the paint and the amount of disintegration it shows. However, other features, such as heavy chalking, or a very hard, flinty surface, which will not allow of a ready penetration, etc., must be considered. Probably the most treacherous surface is the one where the old disintegrated surface will in time flake, forcing off the new paint.

COVERING PROPERTIES

This condition was judged entirely from the concealment of the surface of the wood, afforded by the paint coat. The tints almost invariably offered good hiding qualities, but not so the whites. Especially where the chalking was excessive the concealment was very noticeably lessened.

COLOR

The white tests, alone, were observed for color. This condition was modified considerably by the hiding power of the paint. Portions of lumber that show through the paint influence a yellowish or brownish tinge. This was demonstrated clearly in tests 102 and 103, where two coats were applied over an ochre primer. The color of the three coat test was good, while that of the two coats over an ochre primer was of a pronounced brawny nature, due to the ochre surface showing through.

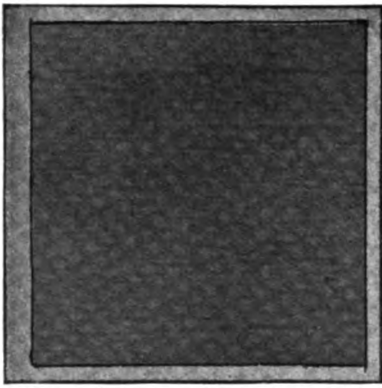

Fig. 1. Surface with no noticeable defect.

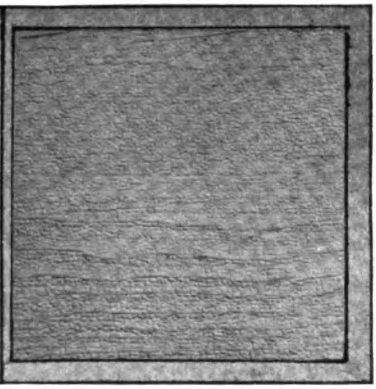

Fig. 2. Surface showing checking.

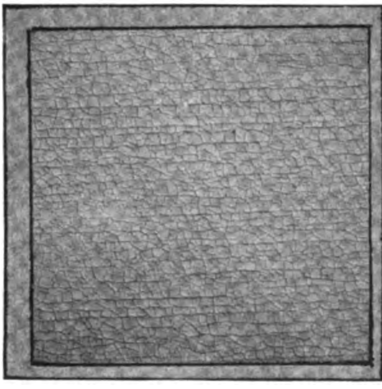

Fig. 3. Checking more pronounced than in Fig. 2.

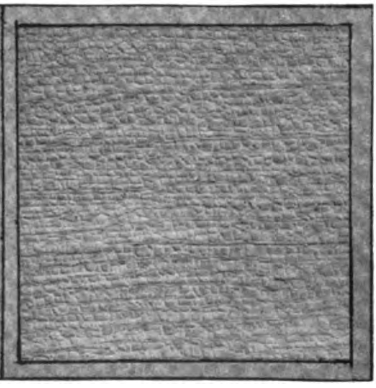

Fig. 4. Alligatoring.

CHALKING

This condition was made as nearly comparable as possible, by rubbing equal sizes of black velvet cloth over equal representative surfaces on the several tests. Care was taken that all other conditions were the same. These strips of cloth were then placed into several groups and in this manner fairly accurate judgment could be made.

PHYSICAL CONDITION OF PAINT SURFACE

This condition is undoubtedly the most important observed. Special care was exercised in determining the characteristic and thoroughtly representative wear of each test, the extent of the disintegration of the paint film, etc., while in most cases this could be determined by the naked eye, it was deemed advisable to use magnification, and throughout the inspection a hand-glass magnifying eight diameters was used. With this glass it was possible to note the finest break in the film, also to determine its depth and nature.

There are several distinct features noted. First, *checking*, entirely a surface defect. It is due to the contraction of the surface and exhibits a "crazed" or broken appearance, extending down to the priming coat in places, but never reaching to the surface of the wood. This is characteristic of Corroded White Lead, and also, in a measure, of Sublimed White Lead.

ALLIGATORING

Is a very pronounced or excessive checking. Here the break in the surface almost invariably extends to the priming. The contraction in this case is abnormally great. In checking and alligatoring the breaks in the surface extend in every direction, with varying degrees of uniformity.

CRACKING

Is the condition observed in the paint film where the break extends through to the wood. It may be, and generally is, along the grain of the lumber, or it may be, as is sometimes noticed, in any direction. Cracking is the fore-runner of greater defects, for it allows the moisture to get to the wood, capillary attraction carries it throughout the wood and soon small pieces of the paint film curl up at the edges of the broken surfaces and come off. This is called *Flaking*. A more pronounced condition arises where large pieces of the paint film become loosened, and Scaling is noted.

PEELING

Was not found in any of the tests. This is an abnormal condition, due to adverse conditions of painting or improper application, and not the outcome of natural wear.

GLOSS

Used in its real meaning could not be applied to the tests. Rubbing will invariably reveal a fairly glossy surface by reflected light, but as this creates an abnormal condition it was deemed best not to report on this feature.

CLASSIFICATION OF TESTS

The tests will be taken up in the order of their relation to the individual pigments, corroded white lead, sublimed white lead, and zinc oxide. Then will be classed together the paints that may be mixtures of these individuals in different proportions, but without the admixture of other constituents.

This brings out as a separate division such paints as may have been compounded from one or more of these bases, with such additions as calcium carbonate, barium sulphate, magnesium silicate, silica, etc.

In addition to such tests, a few were run, in which the variable quantity was the vehicle, some having the turpentine added in amounts differing from usual practice, while others had their turpentine replaced either partially or wholly by benzine.

The illustrations used will be from tests, that, in our opinion, show conditions average of all tests in the particular group to which each particular one belongs; and it will be upon these representative tests alone, that a complete report will be given covering soft pine and cedar, east ex-

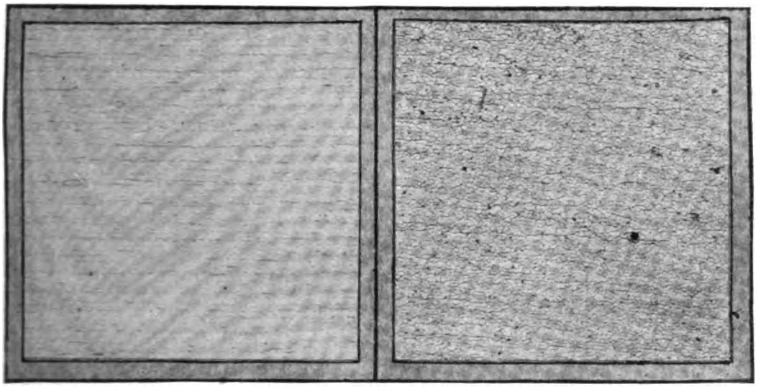

Fig. 5. and Fig. 6. Pronounced checking together with slight cracking.

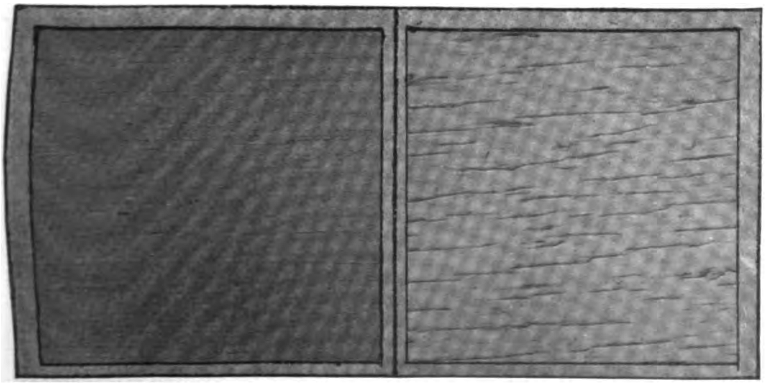

Fig. 7 and Fig. 8. Cracking in advanced stage.

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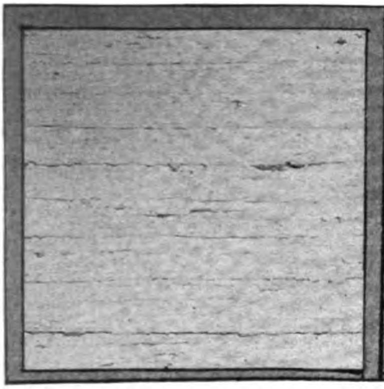

Fig. 9. Flaking in first stage.

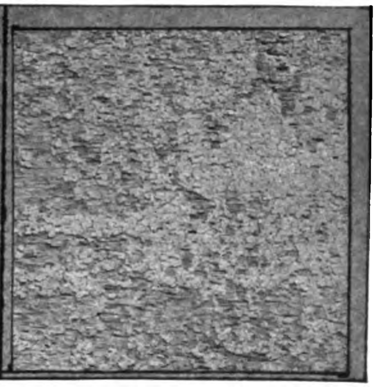

Fig. 10. Flaking advanced.

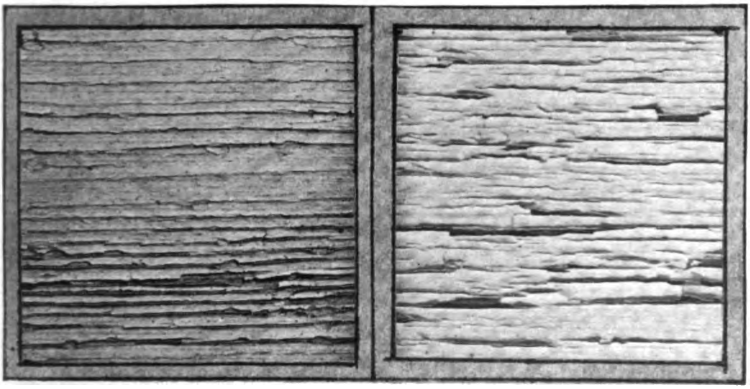

Fig 11 and Fig. 12. Scaling.

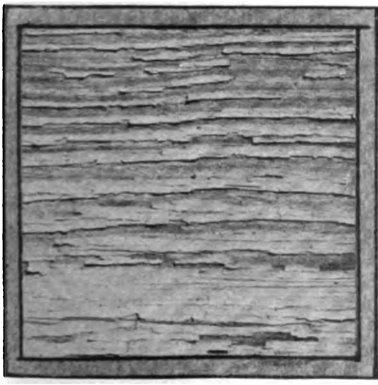

Fig. 13. Disintegration by Scaling

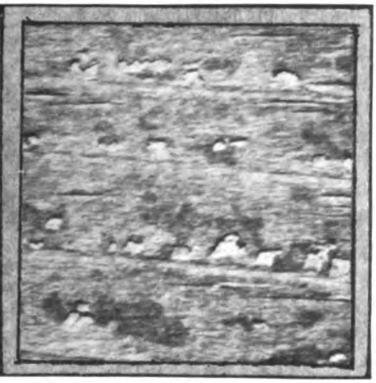

Fig. 14. Disintegration by Flaking.

Fig. 15. Corroded White Lead, Hard Pine.

Fig. 16. Corroded White Lead, Soft Pine.

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posure; hard and soft pine, west exposure. In reporting on all other tests, data will be given upon soft pine, east exposure, the concensus of opinion being that the relative differences in condition are the same.

It may be well to emphasize the fact that the classification here used is one entirely of convenience, rather than an attempt to rank the different paints according to an individual idea of relative quality.

GROUP I. A. This group includes all of the corroded white leads.

Where the test was made under unusual conditions of vehicle or surface, reference is made to the group in which such special test is reported.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
25a	17	White	Med.	Poor	Good	Good	....	Badly	....	Badly	Consid.	....
25b	....	Grey	Good	Fair	Good	.....	....	Consid.	....	Slight	....	....
25c	....	White	Med.	Poor	Good	Good	....	Badly	....	Badly	Consid.	....
25d	....	Grey	Good	Fair	Good	.....	....	Consid.	....	Slight	....	....
25e	....	White	Fair	Fair	Good	Good	....	Badly	....	Consid.	....	....
25f	....	Grey	Good	Fair	Good	.....	....	Badly	....	Slight	....	....
25g	....	White	Fair	Fair	Good	Good	....	Badly	....	Consid.	....	....
25h	....	Grey	Good	Fair	Good	.....	....	Consid.	....	Slight	....	....
27e	18	White	Fair	Fair	Good	Good	Consid.	Badly	....	Consid.	....	....
28e	19	White	Fair	Fair	Good	Good	....	Badly	....	Badly	....	....
34e	23	White	Med	Med	Good	Fair	....	Badly	....	Badly	Slight	....
41h	S. I. T. 1	White	Fair	Fair	Good	Good	Consid.	Badly	....	Badly	....	....
65e	100	White	Good	Fair	Good	Good	Consid.	Badly	....	....	....	....
67e	106	Yellow	Good	Good	Good	Good	Slight	Slight	....	....	....	....
67f	107	Drab	Good	Good	Good	Good	Slight	....	....	....	....	....
71e	116	White	Good	Good	Good	Good	Heavy	Badly	Slight	....	....	....
71f	117	Drab	Good	Good	Good	Good	Medium	Consid.	Slight	....	....	....
78e	130	White	Fair	Fair	Good	Good	Consid.	Badly	....	Consid.	....	....
78f	131	Grey	Good	Good	Good	Good	Consid.	Slight	....	Slight	....	....
68	108	See Group V.										
68	109	"	"	"								
69	110	"	"	"								
69	112	"	"	"								
66	102	"	"	"								
66	104	"	"	"								
80e	134	White	Good	Good	Good	Good	Medium	Badly	....	Consid.	....	....
80f	135	Yellow	V. G	Good	Good	Good	V. Slight	....	....	....	....	....

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligatoring	Cracking	Flaking	Scaling
81e	137	White	Poor	Poor	Good	Good	Medium	Badly	...	Badly	Consid.	...
80f	136	Grey	V G	Good	Good	Good	V. Slight	...	...	...	...	...
81f	138	Yellow	V G	Good	Good	Good	V. Slight	...	...	...	...	...
81f	139	White	Good	Good	Good	Good	Consid.	Badly	...	Slight	...	...
H 8	West	Drab	V P	V P	Med	...	...	Slight	...	V. Badly	...	* Medium
H 8	South	Drab	Fair	Fair	Fair	...	Consid.	Slight	...	Medium	...	...
H 8	East	Drab	Med	Med	Fair	...	...	...	...	Medium	Consid. (in spots)	(in spots)
H 8	North	Drab	Good	Good	Good	...	...	...	...			...
H 9	West	Drab	Good	Good	...	...	Consid.	...	...		...	...
H 9	East	Drab	Good	Good	...	...	Consid.	...	...		...	...
H10	East	Green	Good	Good	Good	...	...	...	...	...	...	...
H10	West	Green	Med	Poor	...	...	...	Slight	Consid.	...	...	...
H11	N.	White	Med	Med	Fair	Good	...	...	Consid.	Consid.	Slight	V. Slight
H11	S.	White	Good	Good	Good	Good	Slight	Consid.	...	Slight	...	...
H12	N.	White	Poor	Poor	...	...	...	...	...	Consid.	...	...
H12	S.	White	Poor	Poor	Fair	Fair	...	Badly	...	Consid.	Badly	Badly (in spots)
H13	E.	Drab	Fair	Fair	...	...	...	...	...	Consid.		
H13	W.	Drab	Fair	Fair	...	...	...	...	...	...	...	...
H14	W National	White	Good	Good	Good	Good	...	...	...	...	...	...
H14	W Acme 1	White	Good	Good	Good	Good	...	...	...	...	...	...
H14	S Acme 2	White	Fair	Fair	Good	Good	Slight	Slight	...	Medium	...	...
H14	S English	White	Good	Good	Good	Good	...	Consid.	...	V. Slight	...	...
H14	E National	White	Good	Good	Good	Good	...	...	...	...	...	...
H14	E Acme 1	White	Fair	Fair	Good	Good	...	Slight	...	Consid.	...	...
H14	N Acme 2	White	Fair	Fair	Good	Good	...	Slight	...	Medium	...	...
H14	N English	White	Good	Good	Good	Good	Slight	...	...	...	...	...

* Paint coat exceedingly brittle.

GROUP I. b.

SUBLIMED WHITE LEAD

The examples of sublimed white lead used as an individual pigment are limited to two on the test fences and two on house tests.

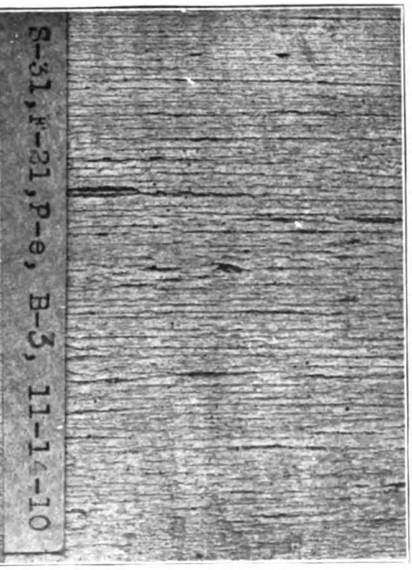


Fig. 17. Sublimed White Lead.

Fig. 18. Zinc Oxide.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
30a	20	White	Poor	Poor	Med	Good	Heavy	....	....	Badly	....	Consid.
b	....	Grey	Poor	Poor	Fair	Good	Heavy	....	....	Badly	....	Consid.
c	....	White	Poor	Poor	Med	Good	Heavy	....	....	Badly	....	Consid.
d	....	Grey	Poor	Poor	Fair	Good	Heavy	....	....	Badly	....	Consid.
e	....	White	Med	Med	Med	Good	Heavy	....	....	V. Badly	....	Slight
f	....	Grey	Med	Med	Fair	Good	Heavy	....	....	Consid.	....	....
g	....	White	Poor	Poor	Med	Good	Heavy	....	....	V. Badly	....	....
h	....	Grey	Med	Poor	Fair	Good	Heavy	....	....	Consid.	....	....
2'06	2	White	Fair	Med	Fair	Good	Heavy	Consid.	....	Slight	....	....
H 2	.... S	Brown	Fair	Fair	.....	.....	Badly	Slight	....	V. Slight	....	....
H 2	.... N	Brown	Med	Med	.....	.....	Badly	Slight	....	Con (hail)	....	....
H 3	.... E	White	Fair	Fair	Good	Good	Consid.	Slight	....	Consid.	....	....

GROUP I. c.—ZINC OXIDE

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
31a	21	White	V P	Poor	Good	Poor	V. Slight	....	....	V. Badly	....	V. Badly
b	....	Grey	V P	Poor	Good	.....	V. Slight	....	....	V. Badly	....	V. Badly
c	....	White	Poor	Poor	Good	Poor	V. Slight	....	....	V. Badly	....	Badly
d	....	Grey	Med	Poor	Good	.....	V. Slight	....	....	Badly	....	Slight
e	....	White	Poor	Poor	Good	Poor	V Slight	....	....	V. Badly	....	Consid.
f	....	Grey	Med	Med	Good	.....	V. Slight	....	....	Badly	....	Slight
g	....	White	Poor	Poor	Good	Poor	V. Slight	....	....	V. Badly	....	Consid.
h	....	Grey	Med	Med	Good	.....	V. Slight	....	....	Badly	....	Slight
44e	SIT 10	White	Fair	Fair	Good	Med	V. Slight	....	....	Consid.	....	....

GROUP II. MIXTURES OF INDIVIDUAL PIGMENTS

Fig. 19. Corroded White Lead 50, Zinc Oxide 50; 4 years exposure.

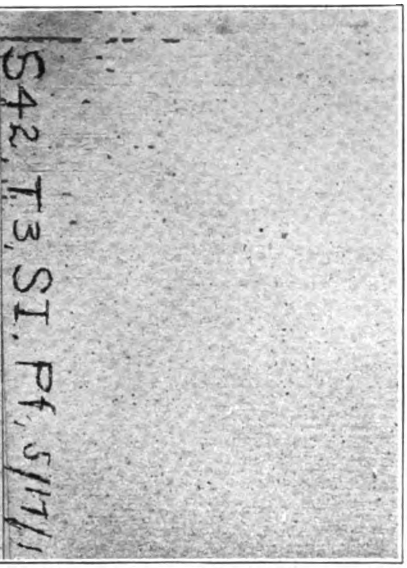


Fig. 20. Corroded White Lead 80, Zinc Oxide 20; 4 years' exposure.

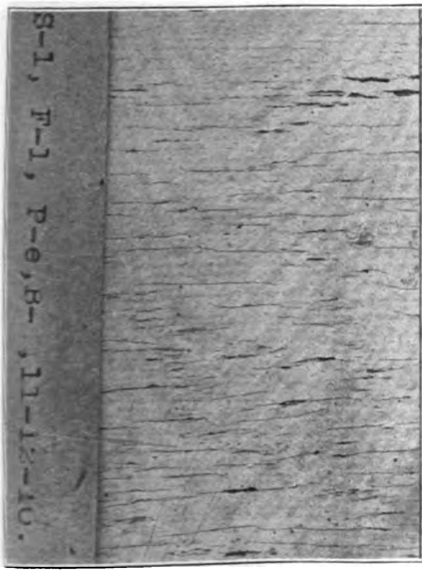


Fig. 21. Corroded White Lead 30, Zinc Oxide 70; Soft Pine; 3 years' exposure.

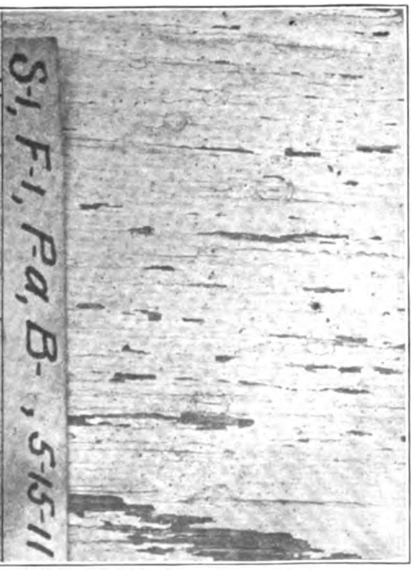


Fig. 22. Corroded White Lead 30, Zinc Oxide 70; Hard Pine; 3½ years' exposure.

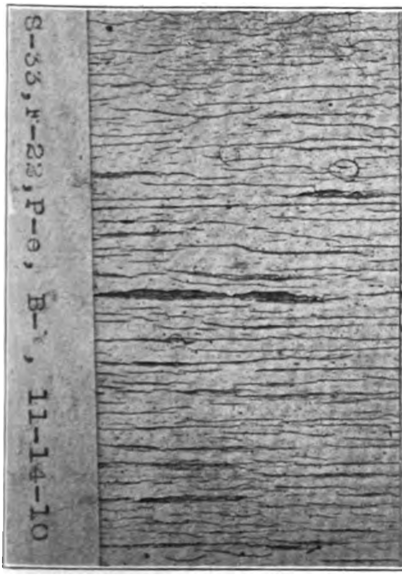


Fig. 23. Standard Zinc Lead White.

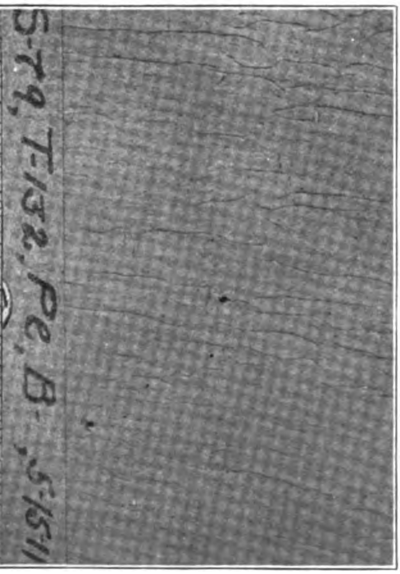


Fig. 24. Sublimed White Lead 60, Zinc Oxide 40.

UNIV. OF

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
3a	3–06	White	Fair	Fair	Good	Fair	Slight	Consid	....	Slight	Slight	....
b	....	Grey	Fair	Fair	Good	.....	Slight	Consid.	....	Slight	Slight	....
c	....	White	Poor	Poor	Good	Med	Slight	Consid.	....	Badly	Badly	along grain
d	....	Grey	Med	Poor	Good	.....	Slight	Consid.	....	Badly	Consid.	....
e	....	White	Fair	Med	Good	Fair	Slight	Consid.	....	Consid.	Slight	....
f	....	Grey	Fair	Med	Good	.....	Slight	Consid.	....	Consid.	Consid.	....
g	....	White	Fair	Med	Good	Fair	Slight	Consid.	....	Consid.	Consid.	....
h	....	Grey	Fair	Med	Good	.....	Slight	Consid.	....	Consid.	Consid.	....
65f	101	White	Good	Fair	Good	Good	Medium	Consid.	....	Consid.	....	....
1e	1	White	Poor	Poor	Good	Poor	V. Slight	....	....	Badly	Badly	Medium
79e	132	White	Med	Poor	Fair	Fair	Consid.	....	....	Badly	....	....
42e	SI T2	White	Fair	Fair	Good	Fair	Consid.	Badly	....	Badly	Slight	....
70e	114	Drab	Fair	Poor	Good	Good	Consid.	Consid.	....	Consid.	Slight	....
70f	115	Drab	Fair	Poor	Good	Good	Medium	Consid.	....	Badly	Slight	....
72e	118	Drab	Good	Good	Good	.....	Medium	Slight	....	Consid.	....	....
H 10	52 S	Green	Good	Fair	Good	.....	....	Slight	Consid.	....	....	....
	N	Green	Good	Med	.....	.....	....	....	....	....	....	....
H 10	50 N	Green	Med	Med	.....	.....	....	V. Slight	....	Medium	....	*
	S	Green	Good	Good	Good	.....	....	....	....	....	....	....
H 10	51 N	Green	Fair	Poor	.....	.....	....	Slight	....	....	....	....
	S	Green	Good	Good	Good	.....	....	V. Slight	....	....	....	....
5-'06e	5	White	Poor	Poor	Fair	Fair	Slight	....	....	Badly	Badly	....
H 3	1 N	White	Fair	Fair	Good	Good	....	Consid.	....	Medium	....	....
	S	White	Fair	Med	Good	Fair	Slight	....	....	Medium	....	....
H8	1 N	Drab	Med	V P	Fair	.....	....	....	....	Badly	Consid.	Consid.

* Paint coat brittle.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligatoring	Cracking	Flaking	Scaling
H 13	1 E	Drab	Med	Poor						Badly	V. Slight	
	W	Drab	Med	Poor						Badly	V. Slight	
43f	SI–T7	White	Poor	Poor	Good	Poor	Slight	Slight		V. Badly	Consid.	
79a	132	White	Poor	Poor	Good	Fair	Consid.			V. Badly		Consid.
c		White	Poor	Poor	Good	Fair	Consid.			V. Badly		
e		White	Med	Poor	Fair	Fair	Consid.			Badly		
g		White	Poor	Poor	Fair	Fair	Consid.			Badly	Slight	
4–06e	4	White	Med	Med	Good	Fair	Consid.	Slight		Badly	Consid.	
77f	129	Grey	Fair	Poor	Good		Slight			Consid.		Slight
77e	128	White	Med	Poor	Fair	Med	Slight			Badly		Slight
33e	22	White	Poor	Poor	Good	Fair	Medium			V. Badly		Bd.,

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
42f	SI-T3	White	Fair	Fair	Good	Fair	Consid.	Consid.		Badly	Consid.	
42g	SI-T4	White	Good	Good	Good	Med	Medium	Consid.		Slight		
72f	119	Drab	Good	Good	Good		Medium					
H.1	2 N	Drab	Med	Med				Slight		Consid.*		
	S	Drab	Med	Med			Consid.			Badly		
H.2	11 E	Drab	Good	Good								
	W	Drab	Poor	Poor						V. Badly	Slight	
H.4	2 E	White	Fair	Fair	Good	Good				Medium		
H.7	11 W	Drab	Fair	Fair	Good		Slight	Consid.		Medium		
H.8	2 N	Drab	Fair	V. Poor	Fair					Badly *		
H.10	53 N	Green	Good	Fair								
	S	Green	Good	Good	Good			V. Slight	Consid.	Slight		
H.13	11 N	Drab	Good	Good	Good							
	S	Drab	Good	Good	Good							
H.13	2 E	Drab	Fair	Fair						Consid.	Slight	
	W	Drab	Fair	Fair						Consid.	Slight	
42h	SI-T5	White	Fair	Fair	Good	Med	Medium	Consid.		Slight		
10e	7	White	Poor	Poor	Good	Med				Badly		Consid.
14'06	16	Yellow	Fair	Fair	Good		Slight	Consid.		Consid.	Slight	
H.4	7 N	White	Med	Med	Good	Good				Medium		
H.13	7 E	Drab	Fair	Fair						Consid.		
	W	Drab	Fair	Fair						Consid.		
43e	SI-T6	White	Med	Med	Good	Poor	Slight	Slight		Consid.		

* Due to hail.

GROUP III.

INDIVIDUAL PIGMENT AND INERT

This class is represented by zinc and inert, there being no tests in which either of the other basic pigments is used with an inert without the presence of one of the other bases.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
10f	-12-06	White	Good	Good	Good	Good	Consid.	Slight	....	Slight	Slight	....
11e	-13-06	See Group V c.										
79f	133	Fawn	Poor	Poor	Good	.....	Medium	....	....	Badly	Slight	....
13f	-15-06	Grey	Med	Med	Good	.....	....	....	....	Consid.	Consid.	....
9e	6	White	V P	Poor	Good	Poor	....	....	....	V. Badly	Badly ...	....
H.4	6 E	White	Med	Med	Good	Fair	....	....	....	Badly	....	....
H.13	6 E	Drab	Fair	Fair	.....	.....	....	....	....	Consid.	....	....
	W	Drab	Fair	Fair	.....	.....	....	....	....	....	....	....
13e	9	White	Med	Poor	Good	Med	....	....	....	Badly	....	Consid.
H.3	9 N	White	Fair	Fair	Good	Good	....	....	....	Consid.	....	....
	S	White	Med	Med	Good	Good	Consid.	....	....	....	....	....
H.13	9 N	Drab	Good	Good	Good	.....	....	....	....	....	....	....
	S	Drab	Good	Good	Good	.....	....	....	....	....	....	....

GROUP IV. LEAD, ZINC AND INERT

Representatives of this class are numerous, the examples selected showing conditions average for this group.

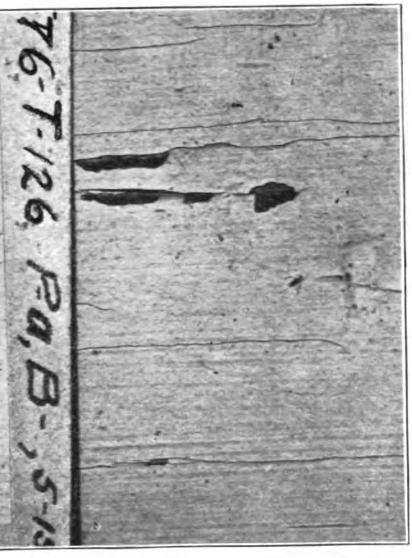
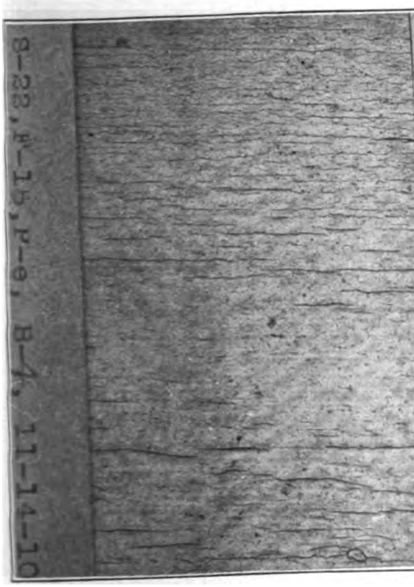


Fig. 25. Corroded White Lead, Zinc Oxide, Silica; Soft Pine.

Fig. 26. Corroded White Lead, Zinc Oxide, Silica; Hard Pine.



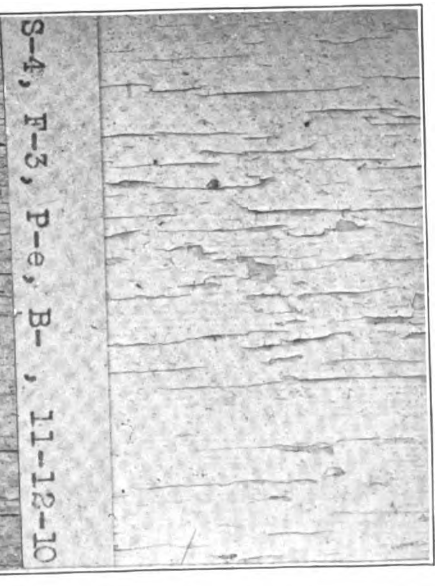


Fig. 27. Sublimed White Lead, Zinc Lead, Zinc Oxide, Calcium Carbonate.

Fig. 28. Corroded White Lead, Sublimed White Lead, Zinc Oxide, Calcium Carbonate.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
12a	8	White	V P	Poor	Good	Med	Slight	...	...	V. Badly	...	V. Badly
b	...	Grey	V P	Poor	Good	...	Slight	...	...	V. Badly	...	V. Badly
c	...	White	Poor	Poor	Good	Med	Slight	...	...	Badly	...	Consid.
d	...	Grey	Poor	Poor	Good	...	Slight	...	...	Badly	...	Consid.
e	...	White	Med	Med	Good	Fair	Slight	...	...	Badly	...	Slight
f	...	Grey	Med	Med	Good	...	Slight	...	...	Consid.	...	Slight
g	...	White	Poor	Poor	Good	Fair	Slight	...	...	V. Badly	...	Badly
h	...	Grey	Fair	Fair	Good	...	Slight	...	...	Medium	...	Badly
22a	15	White	V P	Poor	Good	...	Medium	...	...	V. Badly	...	V. Badly
f	...	Grey	Poor	Poor	Good	...	Medium	...	...	Badly	...	Badly
c	...	White	Poor	Poor	Good	...	Medium	...	...	Badly	...	Badly
d	...	Grey	Med	Poor	Good	...	Medium	...	...	Badly	...	Slight
e	...	White	Med	Poor	Good	Fair	Medium	...	...	Badly	...	Slight
f	...	Grey	Fair	Fair	Good	...	Medium	...	...	Consid.	...	Slight
g	...	White	Poor	Poor	Good	Fair	Medium	...	...	Badly	...	Consid.
h	...	Grey	Med	Poor	Good	...	Medium	...	...	Badly	...	Slight
4a	3	White	Poor	Poor	Good	Fair	Medium	...	...	V. Badly	...	Badly
b	...	Grey	Poor	Poor	Good	...	Medium	...	...	Badly	...	Badly
c	...	White	Poor	Poor	Good	Fair	Medium	...	...	Badly	...	Badly
d	...	Grey	Med	Poor	Good	...	Medium	...	...	Badly	...	Consid.
e	...	White	Poor	Poor	Good	Fair	Medium	Slight	...	Badly	...	Badly
f	...	Grey	Fair	Med	Good	...	Medium	Medium	...	Medium	Slight	Slight
g	...	White	Fair	Fair	Good	Good	Medium	...	...	Consid.	...	Slight
h	...	Grey	Good	Fair	Good	...	Medium	...	...	Slight	...	...

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
6e	6'06	White	Good	Good	Good	Fair	Slight	Consid.	....	Slight	Slight	....
8e	8'06	White	Good	Good	Good	Fair	Slight	Consid.	....	Consid.	Slight	....
6e	4	White	V P	Poor	Good	Poor	Slight	....	....	V. Badly	Badly	....
7e	5	White	Fair	Fair	Good	Fair	....	....	....	Consid.	....	Slight
76e	126	White	Poor	Poor	Good	Fair	Slight	....	....	Badly	....	Slight
15e	10	White	Poor	Poor	Good	Med	Slight	Medium	....	V. Badly	Badly	....
18e	12	White	V P	Poor	Good	Med	Slight	Medium	....	Badly	....	Badly
24e	16	White	Poor	Poor	Fair	Med	Slight	....	....	Consid.	....	Consid.
73e	120	White	Poor	Poor	Good	Med	....	....	....	Badly	....	Slight
73f	121	Drab	Med	Poor	Good	.....	....	....	....	Badly	....	Slight
75e	124	White	Poor	Poor	Fair	Poor	Medium	....	....	V. Badly	....	Slight
76f	127	Grey	Poor	Poor	Good	Fair	Slight	....	....	Badly	....	Slight
H. 1	4 W	Drab	Good	Fair	Good	.....	....	....	....	V. Slight	....	....
	E	Drab	Med	Med	.....	.....	Consid.	Slight	....	Consid.	....	....
H. 13	4	Drab	Fair	Fair	Good	.....	....	Slight	....	Medium	....	....
H. 2	5 S	Brown	Good	Good	.....	.....	....	....	....	....	....	....
	N	Brown	Poor	Poor	.....	.....	....	....	....	....	....	....
H. 6	15 N	Yellow	Fair	Fair	Good	Good	....	V. Badly	....	Hail	....	....
	S	Yellow	Good	Good	Good	Good	....	....	....	....	....	....
H. 13	5 W	Drab	Fair	Fair	Fair	Fair	....	....	....	Slight	....	....
H. 12	5 N	White	Med	Poor	.....	.....	....	Slight	....	V. Badly	Badly	Bd in spots
	S	White	Fair	Fair	Good	Good	....	Slight	....	Slight	....	....
9e	10'06	See Group V c.										
10	11'06	White	Fair	Fair	Fair	Med	Slight	Consid.	....	Consid.	Slight	....

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
H.4	8 S	White	Med	Med	Good	Good	Slight	Consid.	....	Slight	....	....
H.9	8 S	Drab	Good	Good	....	....	....	....	....	....	....	....
	N	Drab	Good	Fair	....	....	....	....	....	....	....	....
H.10	8 W	Green	Good	Good	Good	....	....	....	....	....	....	....
	E	Green	Good	Good	....	....	....	....	....	....	....	....
H.13	8 S	Drab	Fair	Fair	....	....	....	....	....	Medium	....	....
H.5	10 E	Yellow	Good	Good	....	....	Slight	V. Slight	....	....	....	....
	W	Yellow	Poor	Poor	(Hail)		....	....	....	V. Bad *	....	....
H.6	10 E	Yellow	Fair	Fair	Fair	Fair	Slight	....	....	Medium	....	....
	W	Yellow	Poor	Poor	Fair	Fair	....	....	....	Badly	Slight	....
H.7	10 W	Drab	Poor	Poor	Fair	....	Slight	Consid.	....	V. Badly	Consid.	(hail)
	E	Drab	Med	Med	Good	....	Slight	Medium	....	Slight	....	....
H.5	12 E	Yellow	Good	Med	....	....	Slight	....	....	....	....	....
	W	Yellow	Poor	Poor	....	....	....	V. Slight	....	V Bad *	....	....
H.7	12 W	Drab	Poor	Poor	Fair	....	....	Consid.	....	V. Badly	Consid.	....
	E	Drab	Good	Good	Good	....	Slight	Medium	....	V. Slight	....	....
H.1	13 E	Drab	Med	Med	....	....	Consid.	Medium	....	Consid.	Slight	....
	W	Drab	Good	Fair	Good	....	....	....	....	Slight †	....	....
H.7	16 S	Drab	Good	Good	Good	....	Consid.	Consid.	....	Slight	....	....
H.11	120 E	White	Good	Good	Good	Good	....	....	....	....	....	....
H.11	126 E	White	Good	Good	Good	Good	....	....	....	....	....	....

* Not entirely due to hail.

† Protected.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligatoring	Cracking	Flaking	Scaling
19e	13	White	Fair	Fair	Good	Good	Consid.	.....	.....	Consid.	.....	V. Slight
H. 9	13 S	Drab	Good	Med	.....	.....	.....	.....	.....	V. Slight	.....	Peels
	N	Drab	Med	Poor	(some portions very poor)				.....	Slight	Slight	Slight *
H. 12	13 N	White	Fair	Med	Good	Good	Consid.	.....	.....	Medium	V. Slight	Slight
	S	White	Fair	Fair	Good	Good	Consid.	Consid.	.....	Consid.	.....	.....
H. 6	15 N	Yellow	Fair	Fair	Good	Good	Slight	.....	.....	Med (hail)	.....	.....
	S	Yellow	Good	Good	Good	Good	(protected by porch)		.....	.....	.....	.....
H. 9	15 S	Drab	Med	Med	.....	.....	.....	Slight	.....	Consid.	.....	Cons. †
	N	Drab	Good	Good			.....	.....	.....	.....	.....	.....
H. 12	15 W	White	Med	Med	Fair	Fair	.....	.....	.....	Consid.	.....	.....
	E	White	Fair	Good	Good	Good	.....	.....	.....	Medium	.....	.....
H. 11	132 N	White	Poor	Poor	Med	Med	Slight	.....	.....	Badly	Badly	Consid.
	S	White	Good	Good	Good	Good	Slight	Slight	.....	Consid.	Slight	Slight
7e	7'06	White	Poor	V P	Fair	Fair	Slight	Consid.	.....	Badly	Badly	.....
21e	14	White	Poor	Poor	Good	Med	Medium	.....	.....	V. Badly	.....	Consid.
36e	24	White	Med	Poor	Good	Fair	Medium	.....	.....	Badly	.....	Consid.
37e	25	White	V P	Poor	Good	Med	Medium	.....	.....	V. Badly	.....	V. Badly
39e	26	White	V P	Poor	Good	Med	Medium	.....	.....	Badly	.....	Badly
41e	17	White	Med	Med	Good	Fair	Medium	.....	.....	Badly	.....	.....
75f	125	Grey	Poor	Poor	Fair	.....	Medium	.....	.....	V. Badly	.....	Slight

* Paint coat very brittle.

† Considerable under edge of clap boards.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
H.6	3 N	Yellow	Fair	Fair	Good	Good	....	....	....	Medium	....	
	S	Yellow	Good	Good	Good	Good	(protected by porch)					
H.8	3 W	Drab	Poor	Poor	Med	.....	....	Slight	....	V. Badly	Consid.	Badly
	E	Drab	Poor	Poor*	.....	.....	Slight	....	....	Slight	(Repainted in spots)	
H.13	13 N	Drab	Fair	Poor	.....	.....	....	....	....	Con(hail)	....	....
H.13	3 W	Drab	Fair	Med	.....	.....	Consid.	....	....	Consid.	Slight	....
H.5	14 N	Yellow	Med	Med	.....	.....	Slight	....	....	Medium	....	....
	S	Yellow	Good	Good	.....	.....	....	....	....	....	....	....
H.7	14 W	Drab	Poor	Poor	Fair	.....	....	Consid.	....	V. Badly	Consid.	Slight
	E	Drab	Good	Good	Good	.....	Slight	Medium	....	V. Slight	....	....
H.12	14 W	White	Med	Med	Fair	Fair	....	....	....	Consid.	....	....
	E	White	Good	Good	Good	Good	....	....	....	....	....	....

* Due to bad spots.

GROUP V. This group includes paints in which the vehicle is subject to changes.

GROUP V. a. Unusual proportions of turpentine.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligatoring	Cracking	Flaking	Scaling
16e	11	White	Poor	Poor	Good	Med	Slight	....	....	Badly	....	Badly
68b	109	White	Med	Fair	Good	Good	Medium	Consid.	....	Badly	Slight	....
d	....	White	Fair	Fair	Good	Good	Medium	Consid.	....	Badly	Slight	....
f	....	White	Fair	Fair	Good	Good	Medium	Consid.	....	Consid.	....	....
h	....	White	Fair	Fair	Good	Good	Medium	Consid.	....	Consid.	....	....

Fig. 29. Corroded White Lead, Zinc Oxide; Normal Turpentine Content.

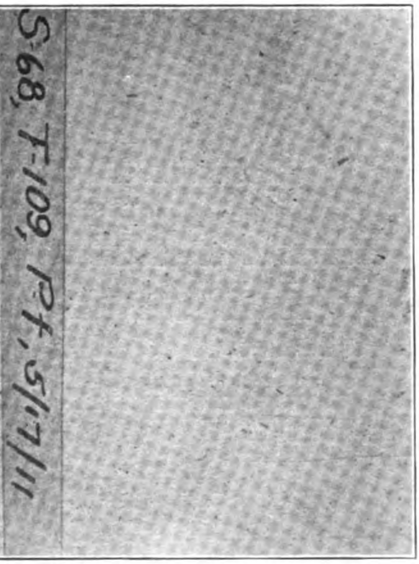


Fig. 30. Same as Fig. 29. High content Turpentine.

Fig. 31. Corroded White Lead 50, Zinc Oxide 50; Vehicle contains 10% Benzine.

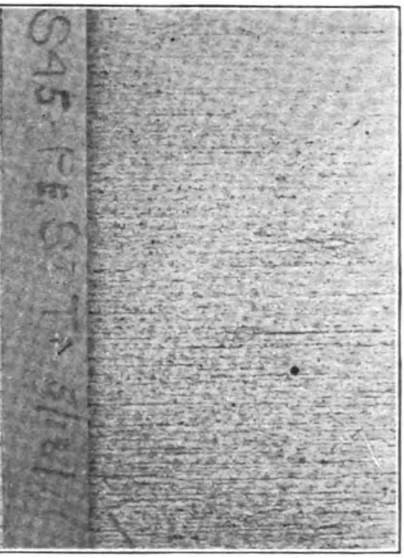


Fig. 32. Corroded White Lead 50, Zinc Oxide 50; Vehicle contains 25% Benzine.

GROUP V. b.

Differing percentages of benzine.

A fairly complete set of these tests was started in fall of 1910; but owing to bad weather only two coats of paint could be applied at the time. These tests will be completed and additional ones made, reports being given at later date.

The tests, influenced by benzine, that have progressed far enough to be of interest, are as follows:

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling]
9–06	See Group V c.											
10–06	See Group V c.											
11–06–13	See Group V.c.											
6e	4	White	V P	Poor	Good	Poor	Slight	....	....	V Badly	Badly	....
13	9	See Group V c.										
19e	13	White	Fair	Fair	Good	Good	Consid.	....	....	Consid.	....	V. Slight
21e	14	White	Poor	Poor	Good	Med	Medium	....	....	V. Badly	....	Consid.
41e	17	White	Med	Med	Good	Fair	Medium	....	....	Badly	....	....
44f	SII, T1	White	Med	Poor	Good	Poor	Medium	....	....	Badly	Slight	....
44g	SII, T2	White	Fair	Fair	Good	Med	Medium	Consid.	....	Consid.	....	....
44h	SII, T3	White	Poor	Poor	Good	Med	Medium	....	....	Badly	Badly	....
45e	SII, T4	White	Med	Med	Good	Poor	Consid.	Consid.	....	Badly	....	....
79	133	See Group V c.										

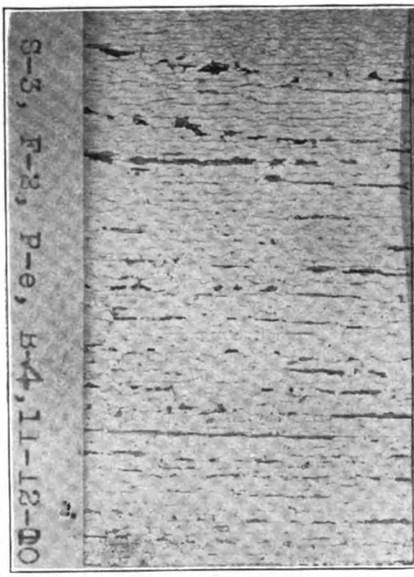


Fig. 33. Corroded White Lead 50, Zinc Oxide 50; Vehicle contains 4% water; 3 years' exposure.

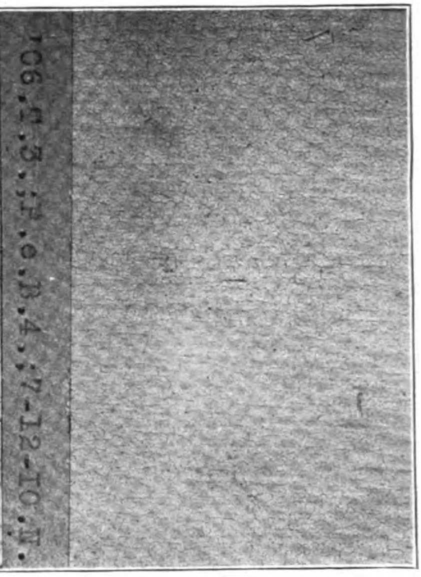


Fig. 34. Corroded White Lead 50, Zinc Oxide 50; Vehicle contains no water; 4 years exposure

GROUP V. c.

Water as a constituent of paint vehicle.

The demonstration of the acknowledged deleterious effect of water as a paint constituent is attended with some difficulty, as in our tests the paints containing large amounts of water are of a formula generally accepted as not of the highest type.

However, the examples selected for illustration show in a degree the ill effects of water.

Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligatoring	Cracking	Flaking	Scaling
9–06f	9	Grey	Poor	Poor	Good	.....	Slight	....	....	Badly	Badly	....
9–06e	10	White	Poor	Poor	Fair	Med	Slight	....	....	Badly	Badly	....
11–06e	13	White	Entirely disintegrated.									
3e	2	White	V P	Poor	Good	Poor	Slight	....	....	V Badly	Badly	Slight
10e	7	White	Poor	Poor	Good	Med	....	....	....	Badly	....	Consid.
13e	9	White	Med	Poor	Good	Med	....	....	....	Badly	....	Consid.
18e	12	White	V P	Poor	Good	Med	Slight	Medium	....	Badly	....	Badly
22e	15	White	Med	Poor	Good	Fair	Medium	....	....	Badly	....	Slight
39e	26	White	V P	Poor	Good	Med	Medium	....	....	V. Badly	....	Badly
75f	125	Grey	Poor	Poor	Fair	.....	Medium	....	....	V. Badly	....	Slight
79f	133	L Fawn	Poor	Poor	Good	.....	Medium	....	....	Badly	Slight	....

GROUP VI.

There is left a final group made up of tests in which the paint coats are of different composition.

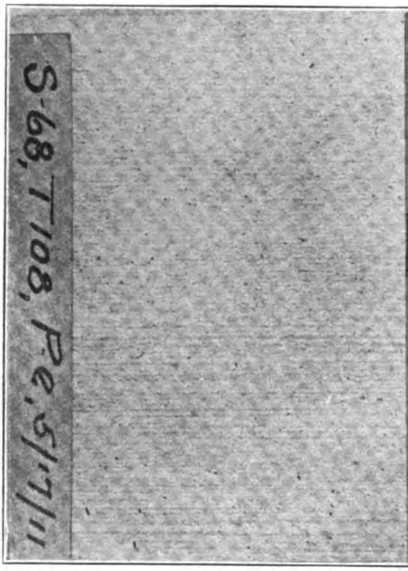


Fig. 35. First Coat, Corroded White Lead. Second and third Corroded White Lead 75, Zinc Oxide 25. Soft Pine.

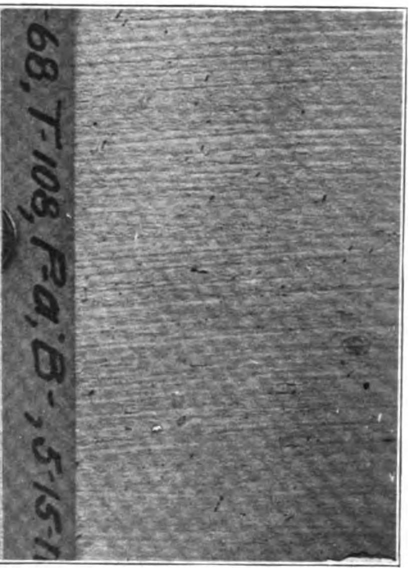


Fig. 36. Same as Fig. 35. Hard Pine.

See also illustrations under heading "Effect of Tint."

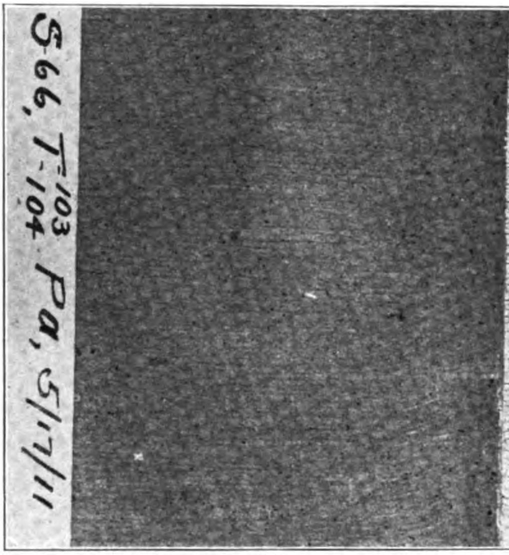


Fig. 37. Two coats Corroded Lead 75, Zinc Oxide 25, over prime coat of Yellow Ochre. Tinted yellow.

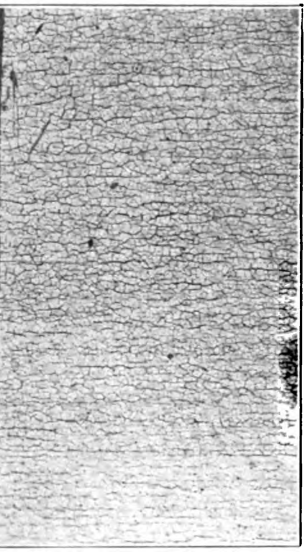


Fig. 38. Same as Fig. 37; White.

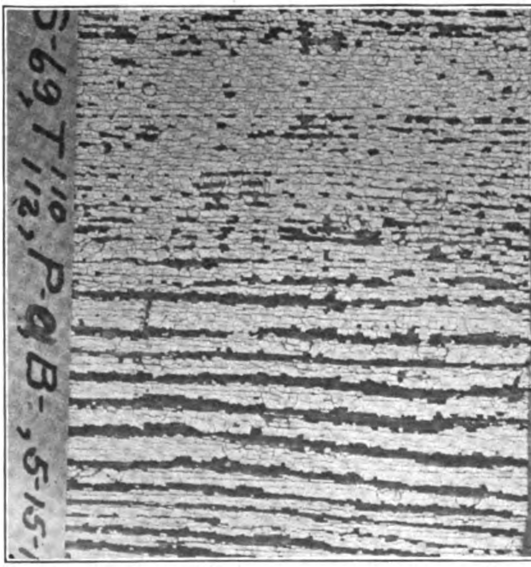


Fig. 39. Two coats Corroded White Lead over Orange Shellac Primer; color White; Hard Pine.

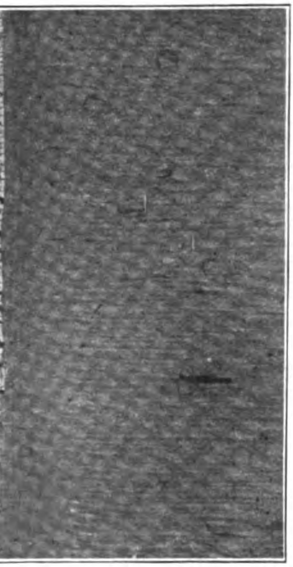


Fig. 40. Same as Fig. 39; tinted yellow.

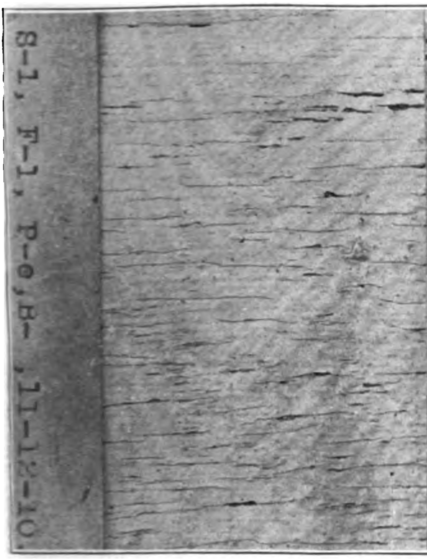
Section and Panel No.	Formula No.	Color	General Condition	Cond. for Repainting	Covering	Color Quality	Chalking	Checking	Alligator-ing	Cracking	Flaking	Scaling
46f	S IV T1	White	Fair	Fair	Fair	Med	Medium	Consid.	....	Consid.	....	....
46g	S IV T2	White	Fair	Fair	Fair	Med	Medium	....	....	Consid.	....	....
46h	S IV T3	White	Med	Med	Good	Med	Consid.	....	....	Badly	Slight	....
66e	102	White	Fair	Med	Fair	Med	Consid.	Badly	....	....	....	....
66f	103	White	Poor	Med	Med	Poor	Medium	V. Badly	Badly	....	....	....
66e	104	Yellow	Good	Good	Good	Good	V. Slight	Slight	....	....	....	....
66f	105	Drab	Good	Good	Good	Good	V. Slight	Slight	....	....	....	....
68e	108	White	Good	Fair	Good	Good	Consid.	Badly	....	Consid.	....	....
68f	109	White	Fair	Fair	Good	Good	Medium	Consid.	....	Consid.	....	....
69e	110	White	Poor	Poor	Med	Fair	Consid.	Badly	....	Badly	Slight	....
69f	111	White	Poor	Poor	Med	Poor	Medium	....	....	Badly	Badly	Consid.
69e	112	Yellow	V G	Good	Good	Good	V. Slight	Slight	....	....	....	....
69f	113	Drab	V G	Good	Good	Good	V. Slight	Slight	....	....	....	....

Without making any attempt to explain the cause of the well known fact, we insert a few illustrations showing the wonderful effect of tint in retarding the disintegration of a paint film.

An examination of the data published in previous bulletins, as well as that under the various groups in this one, will show that with practically no exceptions, tinted paints have a much longer life than white paints under the same conditions of exposure.

It will be noted throughout this report, that fence tests show themselves to be examples of accelerated disintegration of different paint films. This is true with very few exceptions. The instances in which conditions are not comparative being due to some influence exerted on house tests, which did not effect fence tests. An example of this shows up in House Test 9, Formula 13, where paint was put on over old paint, which, although apparently alright at the time, has caused a brittleness of whole film and started a disintegration which cannot help but be extensive within a short time.

Again, in House Test 12, White Lead, there appears to have been damp lumber under cornice and window sills at time of painting, so that now there are some pronounced examples of flaking and peeling.



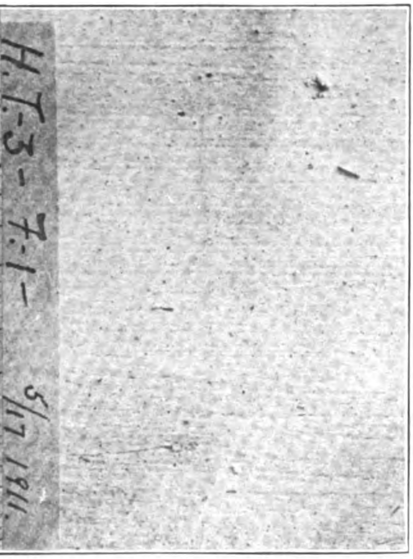


Fig. 41. Corroded White Lead 30, Zinc Oxide 70; 3 years' exposure on Fence.

Fig. 42. Same as 41; 3½ years' exposure on House.

NORTH DAKOTA AGRICULTURAL
COLLEGE

GOVERNMENT
AGRICULTURAL
EXPERIMENT
STATION
FOR NORTH DAKOTA

Bulletin
No. 93

WHEAT INVESTIGATIONS
Milling, Baking and Chemical Tests

BY

E. F. Ladd and C. H. Bailey

Joint Co-operative Work of Experiment Station and the Office of Grain Standardization
of the United States Department of Agriculture

Any farmer, teacher, or student in the State may have this Bulletin
mailed to his address, free of charge, upon application

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June 1911

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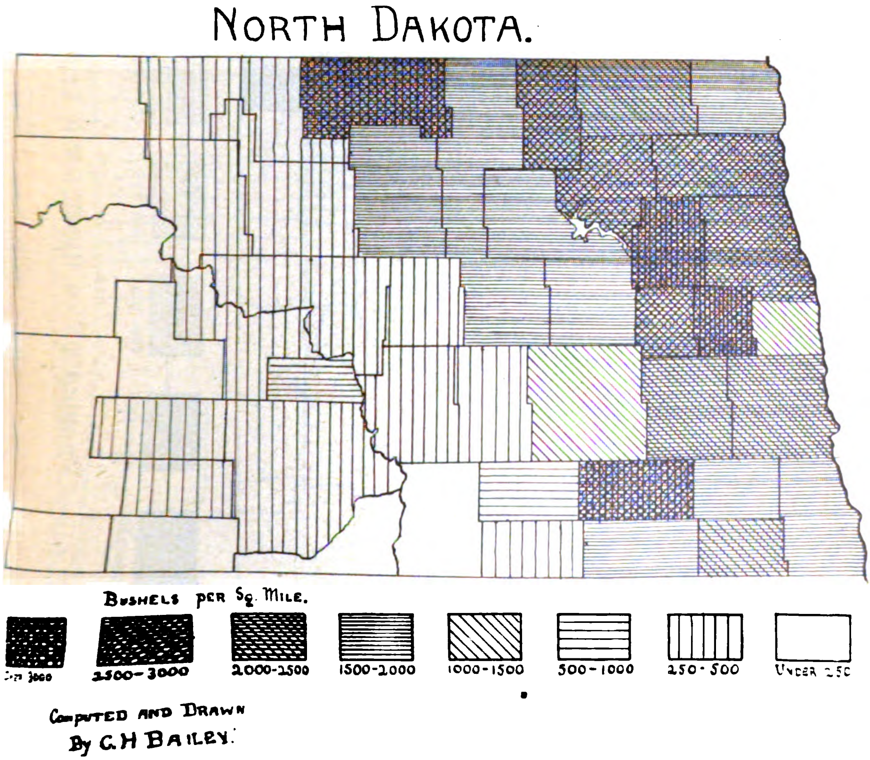
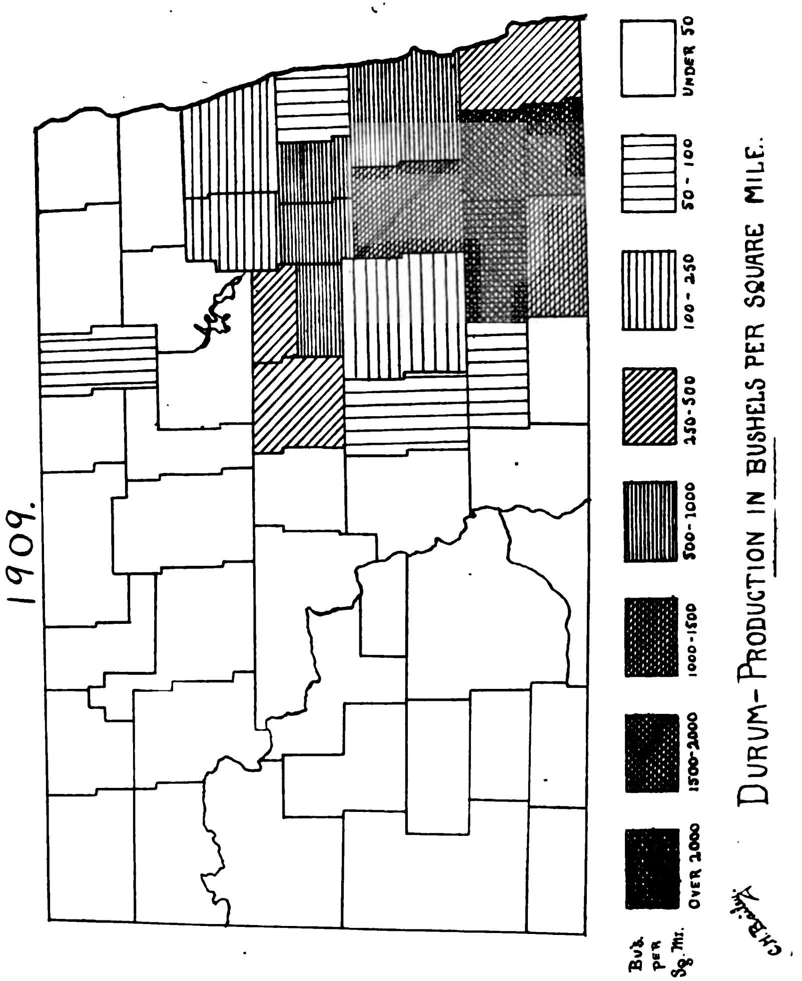
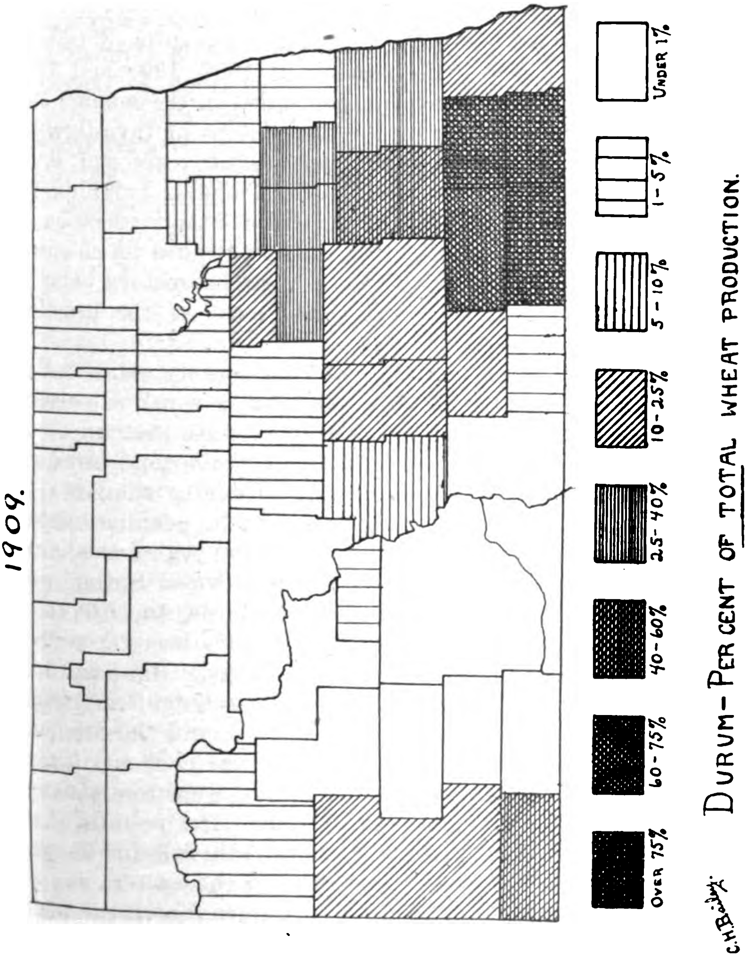
Map I.—Shows graphically the total wheat production (both hard spring and durum) per square mile in North Dakota for 1909, as calculated from tables prepared by W. C. Gilbreath, Commissioner of Agriculture. This map is intended to show where the wheat production is heaviest, the 1909 figures being taken because of the abnormally low production in 1910. This shows a yield of over 3,000 bushels per square mile in Bottineau, Nelson, Steele and LaMoure counties, and over 2,500 bushels per square mile in Towner. Ramsey, Walsh, Grand Forks and Griggs counties, which are the nine leading counties of the State in this respect. producing a total of nearly thirty million bushels or about 34.5% of the total production of the State.



Map II.—Shows graphically the production per square mile of durum wheat in 1909, prepared from Commissioner Gilbreath's tables. This shows LaMoure, Ransom, Sargent, Dickey and Barnes counties to have produced the bulk of the wheat of this class, with a combined yield of over eight and one-half million bushels, or practically 60% of the total durum production of the State.



Map III.—Shows the per cent of the total wheat production of each county, which was durum wheat. In Ransom, Sargent and Dickey counties over 75% of the total crop was durum, while in LaMoure county about 69% was durum. Barnes and Bowman counties were next in order, with 45.4% and 41.2% respectively.



WHEAT INVESTIGATIONS
MILLING, BAKING AND CHEMICAL TESTS

BY E. F. LADD AND C. H. BAILEY

In North Dakota Agricultural Experiment Station Bulletins, Nos. 82 and 89, are set forth the results of tests of wheats grown during the seasons of 1907, 1908 and 1909. These investigations are being continued in the manner outlined in Bulletin No. 89 by the same corps of investigators, Mr. T. Sanderson conducting the milling tests and H. L. White, W. L. Stockham and L. M. Thomas, handling the analytical work. The Office of Grain Standardization of the U. S. Department of Agriculture continues its co-operation with the Experiment Station, their laboratory being in charge of C. H. Bailey, who made most of the practical flour tests.

The 1910 crop samples were very largely submitted by the state demonstration farms and the several Sub-experiment Stations. A number of samples were secured direct from farmers however, particularly in the special investigation of Velvet Chaff wheats conducted during the fall.

The season of 1910 presented certain peculiarities not met with in the preceding seasons during which this investigation has been conducted. An early, warm Spring, with a temperature of 21° above normal in March, and 6.6° above normal in April, was followed by cold, dry weather in May, with less than half the normal precipitation. June and July were both exceedingly hot and dry, the average temperature ranging from 3° to 5° above the normal, and the precipitation being abnormally light. August was cool and favorable for work, but such rains as occurred were too late to be of any value to the small grain crops. The records of the U. S. Weather Bureau show the total rain-fall for the year to have been about half the normal in the eastern sections of the State, and, with but few exceptions, about two thirds of the normal in the western sections. The average of the

State was but 12.34 inches total precipitation, the least in twenty years, and less than 2-3 of the normal.

The effect of these conditions is very fresh in the minds of the farmers, particularly with respect to yields, but it is with the quality and composition of the crop that this investigation is concerned. A study of the tables in the following pages demonstrates the fact that the average quality of the crop from most sections of the State was superior to that of the seasons of 1908 and 1909, so far as loaf volume and gluten were concerned, and the kernels were usually surprisingly plump and well filled, yielding fairly high percentages of flour, providing the samples were dry and well cured. In a number of cases the milling yield was materially reduced by the presence of too high a percentage of moisture, constituting what the miller terms "toughness." and seriously interfering with proper reduction to flour.

METHODS.

The same milling, baking and chemical methods were followed as in the two preceding years, these methods being given in more or less detail in Bulletin No. 89. Certain determinations were discontinued however, as it appeared that they were not of sufficient value to justify the time and labor necessary to carry them out, these being the determination of ether extract, and wet and dry crude gluten by washing. The per cent of crude protein (N x 6.25), gliadin (70%, alcohol soluble nitrogen X 6.25), moisture. acidity, and ash in all the flours milled were determined, and the crude protein (N x 6.25) in the original wheat.

A small two-stand Allis-Chalmers mill was installed in the fall of 1910 for use in producing flour from small samples of wheat, where the quantity available was not sufficient to permit of the use of the large experimental mill. Fifty samples were ground in this way using about 2000 grams (a little less than 5 lbs.) of wheat. In several instances samples were milled on both the large and small mills and on comparing the results, it has been concluded that the small mill will not give accurate results so far as the yield of flour is concerned, but that the qualities of the straight flours produced on the two mills ran about parallel, being slightly inferior in certain respects when produced by the small mill.

FACTORS OF PRINCIPAL IMPORTANCE.

In considering the results of these wheat tests the factors of greatest importance are: First,—the per cent of total, or of straight flour produced; second,—the quality of the high grade flour, patent or straight, as the case may be, as evidenced by the absorption, or water used, in per cent (cubic centimeters per 100 grams of flour), volume of loaf, color of the crumb of the loaf, and the per cent of crude protein. The per cent of total, or of straight flour produced is important because flour is the most valuable product obtained in the milling of wheat. The absorption, or quantity of water used per unit of flour is of importance from the commercial standpoint, because of the influence which this has upon the weight of bread that can be made from a barrel or any other unit of flour. The loaf volume indicates the relative elasticity of the dough, and it is well known amongst bakers and housewives that a flour to make good bread must above all make an elastic dough. Color is of some importance, because most people prefer a white, or only slightly creamy crumb in so called "white bread" made from high grade wheat flour. The color markings are expressed on an arbitrary scale ranging from fifty to one hundred or above, the whiter flours receiving the highest score. Naturally the lower grades or "clear" flours scored lower in color, owing to the way in which they were produced and the mill streams of which they were made up.

A more complete description of the methods and apparatus employed will be found in Bulletin No. 89, to which the reader interested in this phase of the work, is referred.

HARD SPRING WHEATS.

The hard spring wheats of the 1910 crop which were tested belonged to either the Fife, Bluestem, or Velvet Chaff varieties. About half of these samples were milled as straight flours, and the other half separated into the three grades of

Patent, First Clear, and Second Clear flours. The milling tests were accordingly divided into two groups, the samples milled into three grades in one table, and those milled as straights in another table. The baking tests and chemical analyses of all samples were included in the same tables, one column of which indicates the grade of flour. Tables showing the per cent of moisture in the wheats before and after tempering, and the crude protein (N. X 6.25) in the wheat are also included. Tables VII and VIII show the results of the more important tests made on the hard spring wheat samples of the 1910 crop, which may, therefore, be regarded as summaries of the work on each sample and indicates their relative rank and quality.

The following list shows the sample number, variety (when known), and source of the 1910 crop hard red spring wheat samples tested.

List of Hard Red Spring wheat samples, crop of 1910, showing variety and source.

Sample No.	Variety.	Source.
576	Velvet Chaff	**Edgeley, N. D.
577	Minnesota, 163, Fife	**Edgeley, N. D.
596	Velvet Chaff	Kindred, N. D.
597	Velvet Chaff	Christine, N. D.
598	Velvet Chaff	Valley City, N. D.
600	Red Fife	**Dickinson, N. D.
602	Rystings Fife	**Dickinson, N. D.
610	Velvet Chaff	Grandin, N. D.
611	Velvet Chaff	Grandin, N. D.
612	Velvet Chaff	Grandin, N. D.
613	Velvet Chaff	Grandin, N. D.
614	Velvet Chaff	Grandin, N. D.
626	Velvet Chaff	Wheatland, N. D.
628	Fife	*Wahpeton, N. D.
629	Bluestem	*Wahpeton, N. D.
630	Bluestem	Wheatland, N. D.
631	Minnesota 169, Bluestem, Plot 2	*Larimore, N. D.

632	Minnesota 169, Bluestem, Plot 5	*Larimore, N. D.
633	Velvet Chaff	Emerado, N. D.
643	Velvet Chaff	Lisbon, N. D.
644	Haynes Bluestem, North Dakota 316	Agricultural College, N. D.
646	Hard Spring, mill blend	Casselton, N. D.
647	Bluestem	Carrington, N. D.
648	Velvet Chaff	Carrington, N. D.
650	Fife	*New Salem, N. D.
652	Bluestem	Hankinson, N. D.
653	Velvet Chaff	Hankinson, N. D.
655	Bluestem, Plot 1	*Page, N. D.
664	Minnesota 163, Fife, Plot 1	*Lakota, N. D.
676	Bluestem	*Rugby, N. D.
687	Fife	*Jamestown, N. D.
688	Minnesota 169, Bluestem	**Langdon, N. D.
689	Fife	**Langdon, N. D.
691	Bluestem, Plot 6	*Bathgate, N. D.
692	Bluestem	**Williston, N. D.
693	Minnesota, 163 Fife	**Williston, N. D.
694	Fife	*Sanborn, N. D.
695	Fife	*Portland Junct., N. D.
696	Bluestem	Comstock, Minn.
711	Velvet Chaff	Lisbon, N. D.
712	Velvet Chaff	Fargo, N. D.
713	Velvet Chaff	Grandin, N. D.

*State Demonstration Farm.

**Agricultural Sub-Experiment Station.

Table I. Milling tests of the Hard Red Spring wheat samples, crop of 1910, which were separated into three grades of flours.

Sample Number	Wt. per bu. rec'd	Wt. per bu. cleaned	Loss in cleaning	Quantity milled	Bran	Shorts	Total flour	Loss in milling	Total flours divided into		
									Patent	1st clear	2nd clear
	Pounds	Pounds	Per cent	Pounds	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
577	60	62	2.8	68.1	15.5	13.2	74.1	2.8	77.5	18.6	3.9
600	62	64	.6	97.7	10.9	16.7	68.5	3.9	75.4	18.4	6.2
602	59	60	2.9	81.3	10.4	20.4	69.5	a	65.7	29.4	4.9
628	59	61	6.5	103.8	7.8	16.1	75.6	b	74.8	20.0	5.2
629	60	62	1.4	114.1	10.7	15.9	74.4	c	75.0	18.4	6.4
631	58	61	2.4	131.1	13.0	16.2	70.6	.2	74.7	17.6	7.7
632	60	61	2.8	129.6	11.0	15.6	75.2	d	75.8	17.8	6.4
650	58	60.5	.9	115.3	10.5	16.3	69.9	3.2	65.9	29.7	4.4
655	58	60.5	2.7	114.2	13.9	12.6	63.3	5.2	78.1	19.0	2.9
664	60	62.5	3.0	116.4	9.5	15.2	72.5	2.8	75.2	22.5	2.3
676	58	61.5	3.5	113.8	11.0	17.6	69.4	2.3	67.1	29.5	3.4
687	59	62	3.3	110.6	9.2	14.9	78.6	e	75.2	19.9	4.9
688	57	59	.5	124.9	11.1	16.3	68.6	4.0	76.0	20.2	3.8
689	57	60	.7	128.2	12.0	14.1	69.5	4.4	74.4	21.7	3.9
691	42	60	17.9	97.9	9.2	16.8	71.8	2.2	74.8	20.5	4.7
692	59	61	1.0	117.4	10.6	13.6	73.6	2.2	75.0	21.1	3.9
693	60	63	1.5	113.3	8.9	15.3	76.0	f	78.8	17.7	3.5
694	57	61	3.4	114.2	8.5	17.0	73.8	.7	74.8	20.2	5.0
695	60	62.5	2.8	117.1	6.8	16.5	76.5	.2	75.0	21.0	4.0
Average	58	61.3	3.4	111.0	10.6	15.8	72.2	2.6	74.2	21.2	4.6

a—Gain of .3 per cent in milling.
b—Gain of .5 per cent in milling.
c—Gain of 1.0 per cent in milling.
d—Gain of 1.8 per cent in milling
e—Gain of 2.7 per cent in milling
f—Gain of .2 per cent in milling

Table II. Milling tests of the Hard Red Spring wheat samples, crop of 1910, from which straight flours were milled.

Sample Number	Wt. per bu. as received	Wt. per bu. cleaned	Loss in cleaning	Quantity milled	Bran	Shorts and low grade	Straight flour	Loss in milling
	Pounds	Pounds	Per cent	Pounds	Per cent	Per cent	Per cent	Per cent
576	62	63	2.4	126	8.6	22.7	68.2	.5
596	62	65	4.2	102.3	8.6	26.7	69.9	a
597	63	65	3.1	142.8	9.5	26.3	67.5	b
598	61	63	.7	128.2	9.3	24.5	65.5	.6
610	62	64	1.1	117	14.2	19.8	65.5	.5
611	64	66	.9	116.6	10.9	21.6	68.7	c
612	64	64	1.6	117.2	9.3	20.7	66.2	3.8
613	63	64	1.4	140	13.5	19.4	67.5	d
614	62	64	2.4	139.8	10.6	21.9	73.1	e
626	61	63	1.7	119	15.5	20.6	62.2	1.7
630	58	60	4.6	111.5	13.4	23.5	64.6	f
633	62.5	63.5	1.1	110.2	8.8	23.5	66.9	.8
643	60	62	1.2	119.8	14.2	26.4	54.9	4.5
644	59	61.5	1.1	116	9.5	19.7	68.2	2.6
646	----	59.5	cleaned	59.4	10.4	14.2	71.6	1.2
647	58.5	60.5	2.7	121.9	11.2	18.4	66.2	4.2
648	60	62.5	1.4	119.3	9.7	23.0	64.2	3.1
652	60	62	3.2	110.4	13.3	17.5	69.0	1.2
653	58	59.5	4.9	113	10.6	17.1	71.7	.6
696	60	61	.03	631	11.5	17.5	72.9	2.1
711	58	62	1.8	120.4	9.7	19.3	66.4	4.6
712	61	63	3.1	110.4	9.4	15.8	70.8	4.0
713	60	63	1.1	127.5	8.9	17.9	69.8	3.4
Average	60.9	62.6	2.18	114.7	10.9	20.8	67.5	2.3

a—Gain of 5.2 per cent in milling. d—Gain of .4 per cent in milling
b—Gain of 3.3 per cent in milling. e—Gain of 4.9 per cent in milling
c—Gain of 1.2 per cent in milling. f—Gain of 1.5 per cent in milling

Table III. **Moisture in the Hard Spring wheat samples—crop of 1910**

Sample Number	Moisture in wheat before tempering	Moisture in wheat after tempering	Sample Number	Moisture in wheat before tempering	Moisure in wheat after tempering
	Per cent	Per cent		Per cent	Per cent
576	11.8	13.9	647	14.5	14.6
577	11.8	14.2	648	13.9	14.4
596	11.1	14.9	650	14.5	15.0
597	11.1	14.9	652	11.8	13.9
598	13.4	14.6	653	12.8	13.6
600	14.9	15.2	655	12.8	13.6
602	13.2	15.0	664	12.8	13.6
610	14.6	16.7	676	13.6	15.0
611	12.2	13.2	687	13.4	14.5
612	15.0	15.5	688	16.0	16.3
613	13.6	15.4	689	16.8	16.4
614	12.0	16.3	691	12.6	13.2
626	14.7	16.2	692	12.3	12.4
628	11.6	12.6	693	10.9	13.3
629	11.9	14.1	694	12.9	13.0
630	14.3	16.9	695	12.8	14.0
631	12.5	13.7	696	13.5	14.8
632	12.6	13.2	711	15.9	15.7
633	13.0	14.5	712	11.5	11.8
643	16.1	16.9	713	14.0	14.6
644	12.8	14.3	719	13.4	14.4
646	14.7	15.6	Average	13.3	14.5

Table IV. Baking Tests of the Flours Milled from the Hard Spring Wheat Samples—Crop of 1910.

Sample Number	Grade of flour	Water used	Weight of loaf	Volume of loaf	Color
		Per cent	Grams	Cubic Cm.	
576	Straight	59.4	489	2550	97
577	Patent	55.9	485	2675	105
	1st Clear	58.5	500	2370	79
	2d Clear	62.6	514	2060	76
596	Straight	52.4	473	2310	99
597	Straight	54.1	475	2400	102
598	Straight	53.8	480	2450	102
600	Patent	52.1	482	2490	103
	1st Clear	52.9	484	2380	76
	2d Clear	53.2	486	2230	67
602	Patent	50.9	476	2400	96
	1st Clear	50.9	482	2000	91
	2d Clear	52.1	490	1520	57
610	Straight	50.0	475	2400	102
611	Straight	55.3	483	2310	100
612	Straight	50.6	475	2380	102
613	Straight	50.0	476	2420	98
614	Straight	53.2	483	2410	97
626	Straight	49.7	474	2350	105
628	Patent	51.5	475	2310	100
	1st Clear	51.5	480	2270	64
	2d Clear	52.4	487	1600	50
629	Patent	51.8	482	2260	99
	1st Clear	52.6	484	2100	Gray
	2d Clear	52.6	487	1750	Brown
630	Straight	53.8	480	2490	82
631	Patent	53.5	485	2490	96
	1st Clear	54.4	488	2380	79
	2d Clear	55.9	490	2140	50
632	Patent	55.0	487	2590	91
	1st Clear	56.8	495	2470	50
	2d Clear	58.2	502	2240	Dirty
633	Straight	52.4	479	2550	97
643	Straight	53.2	490	2480	105
644	Straight	51.5	478	2420	98
646	Straight	51.5	477	2400	98
647	Straight	51.8	473	2530	99
648	Straight	51.8	480	2430	97
650	Patent	51.5	479	2740	104
	1st Clear	52.6	485	2460	82
	2d Clear	53.5	492	1800	85

Sample Number	Grade of flour	Water used	Weight of loaf	Volume of loaf	Color
		Per cent	Grams	Cubic Cm.	
652	Straight	50.0	477	2460	99
653	Straight	51.5	477	2590	97
655	Patent	50.6	485	2270	105
	1st Clear	51.2	490	1800	88
	2d Clear	51.8	495	1580	70
664	Patent	53.2	482	2750	103
	1st Clear	55.9	495	2200	79
	2d Clear	55.9	498	1940	---
676	Patent	52.1	482	2760	102
	1st Clear	52.9	496	2500	99
	2d Clear	53.5	505	2080	91
687	Patent	51.5	482	2640	100
	1st Clear	52.4	485	2330	64
	2d Clear	53.2	492	1800	L.G.
688	Patent	52.4	483	2640	98
	1st Clear	55.3	493	2380	76
	2d Clear	54.7	498	2050	61
689	Patent	52.1	480	2600	98
	1st Clear	55.3	492	2400	76
	2d Clear	56.8	505	2110	57
691	Patent	51.5	481	2640	101
	1st Clear	51.8	487	2000	61
	2d Clear	52.7	501	1610	50
692	Patent	52.1	481	2650	100
	1st Clear	53.5	489	2050	70
	2d Clear	52.6	496	1650	50
693	Patent	52.4	483	2520	100
	1st Clear	52.9	495	2030	61
	2d Clear	52.9	495	1820	L.G.
694	Patent	53.5	485	2640	100
	1st Clear	52.9	487	2200	67
	2d Clear	53.2	487	1720	50
695	Patent	52.1	480	2520	100
	1st Clear	52.9	490	1900	61
	2d Clear	52.9	494	1580	L.G.
696	Straight	52.6	489	2410	100
711	Straight	51.5	475	2650	100
712	Straight	51.2	478	2230	96
713	Straight	51.8	478	2380	97
719	Straight	50.0	468	2400	98
720	Straight	50.0	474	2400	97
Average	Patent	52.0	481	2518	99.7
	1st Clear	53.2	489	2182	73.2
	2d Clear	53.9	495	1832	61.7
	Straight	52.3	478	2435	98.6

Table V. Chemical Analysis of the Flours Milled from the Hard Red Spring Wheat Samples—Crop of 1910.

Sample Number	Grade of flour	Moisture	Crude Protein N x 6.25	Gliadin N x 6.25	Gliadin number	Ash	Acidity as lactic acid
		Per cent	Per cent	Per cent		Per cent	Per cent
576	Straight	10.51	17.19	9.75	56.7	.60	.202
577	Patent	10.92	15.38	8.88	57.7	.47	.128
	1st Clear	10.69	17.69	10.13	57.2	.66	.204
	2d Clear	9.77	16.88	9.25	55.0	.65	.238
596	Straight	12.40	12.00	7.13	59.4	.54	.157
597	Straight	11.18	13.69	8.19	59.8	.49	.126
598	Straight	11.98	14.81	8.31	56.2	.51	.133
600	Patent	12.40	14.19	8.00	56.4	.46	.153
	1st Clear	12.03	16.44	9.25	56.3	.64	.209
	2d Clear	11.83	15.19	8.75	57.6	.70	.230
602	Patent	11.31	16.31	9.44	57.8	.48	.139
	1st Clear	11.33	17.50	9.75	55.7	.64	.225
	2d Clear	10.51	18.88	10.13	53.6	.84	.335
610	Straight	12.70	12.06	6.81	56.4	.50	.133
611	Straight	11.90	10.81	6.13	56.7	.52	.119
612	Straight	13.39	10.81	6.19	57.2	.46	.112
613	Straight	12.98	12.38	7.44	60.1	.49	.146
614	Straight	12.01	14.63	8.06	55.1	.51	.137
626	Straight	12.20	10.94	6.19	56.5	.53	.108
628	Patent	11.96	10.94	6.25	57.1	.56	.162
	1st Clear	11.08	12.44	6.56	52.8	.82	.270
	2d Clear	10.72	12.50	6.13	49.0	.97	.324
629	Patent	11.29	13.00	6.19	47.5	.55	.157
	1st Clear	10.95	11.69	6.44	55.1	.72	.247
	2d Clear	10.56	12.69	6.31	54.5	1.02	.373
630	Straight	11.97	13.75	7.88	57.2	.53	.135
631	Patent	11.06	13.75	7.56	55.0	.52	.151
	1st Clear	11.16	15.00	8.06	53.7	.70	.227
	2d Clear	10.99	15.00	7.63	50.8	.85	.333
632	Patent	11.32	14.81	8.19	55.3	.55	.169
	1st Clear	11.28	16.63	8.06	48.5	.73	.288
	2d Clear	10.73	16.75	8.38	50.0	.91	.378
633	Straight	11.58	15.06	8.88	58.9	.50	.153
643	Straight	11.72	14.13	8.75	62.0	.48	.124
644	Straight	11.37	15.13	7.69	50.6	.58	.189

Sample Number	Grade of flour	Moisture	Crude Protein N x 6.25	Gliadin N x 6.25	Gliadin number	Ash	Acidity as lactic acid
		Per cent	Per cent	Per cent		Per cent	Per cent
646	Straight	12.16	12.06	7.00	50.2	.52	.148
647	Straight	11.63	14.81	8.56	51.9	.58	.155
648	Straight	11.62	15.19	9.56	63.0	.58	.121
650	Patent	11.81	16.31	9.06	56.2	.50	.168
	1st Clear	11.60	17.63	9.81	55.7	.67	.263
	2d Clear	10.63	17.00	8.69	51.1	.83	.346
652	Straight	11.62	11.75	6.94	59.0	.48	.150
653	Straight	11.43	13.06	7.44	56.9	.53	.184
655	Patent	11.04	14.69	8.19	55.8	.53	.130
	1st Clear	10.43	16.44	8.50	51.7	.83	.231
	2d Clear	9.88	17.13	8.44	49.3	.94	.265
664	Patent	11.65	14.44	8.50	58.9	.52	.121
	1st Clear	11.00	16.13	8.69	53.8	.66	.184
	2d Clear	9.93	16.56	8.94	53.9	.80	.281
676	Patent	12.33	15.38	8.50	55.3	.55	.153
	1st Clear	11.36	16.25	8.75	53.8	.66	.195
	2d Clear	10.55	16.19	8.38	51.8	.59	.243
687	Patent	9.88	14.81	8.13	54.8	.50	.123
	1st Clear	9.31	16.56	8.38	50.6	.74	.220
	2d Clear	8.49	17.88	8.31	46.5	1.00	.274
688	Patent	12.21	14.31	7.69	53.7	.56	.121
	1st Clear	11.64	15.25	7.88	51.6	.66	.180
	2d Clear	10.35	16.13	7.88	48.8	.88	.213
689	Patent	12.88	15.44	8.38	54.2	.53	.099
	1st Clear	11.69	16.25	8.50	52.3	.64	.146
	2d Clear	10.57	16.81	8.56	50.9	.77	.213
691	Patent	11.32	13.31	7.00	52.6	.55	.164
	1st Clear	11.18	14.19	7.19	50.7	.90	.319
	2d Clear	10.12	15.25	6.63	43.5	1.00	.373
692	Patent	10.70	12.44	6.38	51.2	.56	.139
	1st Clear	10.34	13.81	6.81	49.3	.85	.267
	2d Clear	9.65	15.00	6.31	42.1	1.10	.389
693	Patent	9.88	14.69	7.69	52.3	.51	.148
	1st Clear	10.11	17.25	8.50	49.3	.90	.207
	2d Clear	9.36	18.19	8.56	47.1	1.00	.326
694	Patent	10.16	16.13	8.88	55.0	.58	.137
	1st Clear	9.69	17.00	8.75	51.5	.77	.207
	2d Clear	8.72	17.81	7.81	44.2	1.00	.267
695	Patent	9.98	13.56	7.38	54.4	.61	.146
	1st Clear	9.42	14.44	7.25	50.2	.83	.202
	2d Clear	8.56	16.25	7.00	43.1	1.20	.346

696	Straight	10.62	12.25	6.63	54.1	.64	.175
711	Straight	10.64	14.38	8.25	57.4	.58	.148
712	Straight	9.57	12.75	7.00	55.3	.64	.200
713	Straight	10.91	12.75	7.38	58.4	.56	.182
Average	Patent	11.26	14.34	7.94	53.5	.52	.142
	1st Clear	10.90	15.74	8.35	53.0	.72	.222
	2d Clear	10.19	16.45	8.15	49.7	.89	.301
	Straight	11.68	13.32	7.66	56.9	.54	.149

Table VI. Crude Protein in Wheat.

Sample number	Crude Protein in wheat N x 6.25	Sample number	Crude Protein in wheat N x 6.25	Sample number	Crude Protein in wheat N x 6.25
	Per cent		Per cent		Per cent
576	18.19	630	14.50	687	16.44
577	16.94	631	15.31	688	16.38
596	13.31	632	16.44	689	16.63
597	16.38	633	16.81	691	13.94
598	16.19	643	15.31	692	12.44
600	16.63	644	15.06	693	16.18
602	18.13	646	13.94	694	16.81
610	13.06	647	16.50	695	14.06
611	11.81	648	16.25	696	13.25
612	11.94	650	18.19	711	15.06
613	13.81	652	13.31	712	13.31
614	16.56	653	14.44	713	14.13
626	11.38	655	15.31	719	11.69
628	12.06	664	16.25		
629	12.94	676	17.06	Average	15.44

Table VII. Results of the more important tests made on the Hard Red Spring Wheat Samples—Crop of 1910, which were separated into three grades of flour.

Sample Number	Total Flour	Patent Flour	TESTS ON PATENT FLOUR			
			Water used	Volume of loaf	Color of loaf	Crude Protein N x 6.25
	Per cent	Per cent	Per cent	Cc.		Per cent
577	74.1	77.5	55.9	2675	105	15.38
600	68.5	75.4	52.1	2490	103	14.19
602	69.5	65.7	50.9	2400	96	16.31
628	75.6	74.8	51.5	2310	100	10.94
629	74.4	75.0	51.8	2260	99	13.00
631	70.6	74.7	53.5	2490	96	13.75
632	75.2	75.8	55.0	2590	91	14.81
650	69.9	65.9	51.5	2740	104	16.31
655	63.3	78.1	50.6	2270	105	14.69
664	72.5	75.2	53.2	2750	103	14.44
676	69.4	67.1	52.1	2760	102	15.38
687	78.6	75.2	51.5	2640	100	14.81
688	68.6	76.0	52.4	2640	98	14.31
689	69.5	74.4	52.1	2600	98	15.44
691	71.8	74.8	51.5	2640	101	13.31
692	73.6	75.0	52.1	2650	100	12.44
693	76.0	78.8	52.4	2520	100	14.69
694	73.8	74.8	53.5	2640	100	16.13
695	76.5	75.0	52.1	2520	100	13.56
Average	72.2	74.2	52.0	2518	99.7	14.34

Table VIII. Results of the more important tests made on the Hard Red Spring wheat samples—Crop of 1910, which were milled as straight flours.

Sample Number	Straight Flour	TESTS ON THE STRAIGHT FLOUR			
		Water used	Volume of loaf	Color of loaf	Crude Protein N x 6.25
	Percent	Per cent	Cc.		Per cent
576	68.2	59.4	2550	97	17.19
596	69.9	52.4	2310	99	12.00
597	67.5	54.1	2400	102	13.69
598	65.5	53.8	2450	102	14.81
610	65.5	50.0	2400	102	12.03
611	68.7	55.3	2310	100	10.81
612	66.2	50.6	2380	102	10.81
613	67.5	50.0	2420	98	12.38
614	73.1	53.2	2410	97	14.63
626	62.2	49.7	2350	105	10.94
630	64.6	53.8	2490	82	13.75
633	66.9	52.4	2550	97	15.06
643	54.9	53.2	2480	105	14.13
644	68.2	51.5	2420	98	15.13
646	71.6	51.5	2400	98	12.03
647	66.2	51.8	2530	99	14.81
648	64.2	51.8	2430	97	15.19
652	69.0	50.0	2460	99	11.75
653	71.7	51.5	2590	97	13.06
696	72.9	52.6	2410	100	12.25
711	66.4	51.5	2650	100	14.38
712	70.8	51.2	2230	96	12.75
713	69.8	51.8	2380	97	12.75
Average	67.5	52.3	2435	98.6	13.32

Tables IX, X and XI show the average results of the milling and baking tests and chemical analysis of the Hard Red Spring and Durum wheat samples of the 1908, 1909 and 1910 crops. These show the hard red springs of the 1910 crop to have yielded a higher average per cent of flour than the wheats of the two preceding crops, with the exception, that those samples which were milled as straight flours included several which were rather damp and "tough" with the result that the low yield of flour obtained from them reduced the average somewhat. That the average quality of the flours was superior to the 1908 and 1909 crop samples tested is evidenced by the results of the baking tests which show the 1910 patents to have given an average loaf volume of 2,518 cubic centimeters, as compared with 2,307 C. C. and

2,461 C. C. for the crop years of 1908 and 1909 respectively.

The Durum wheat samples tested, however, did not compare so favorably with those tested during the two preceding years. The average yield of flour was lower and the quality of flour was apparently not so good, as evidenced by the results of the baking tests, especially so far as loaf volume is concerned.

Table IX. Averages of the results of the milling tests of Hard Red Spring and Durum wheat samples of the 1908, 1909 and 1910 crops.

Class and Crop	Wgt. per bushel as rec'v'd	Wgt. per bushel cleaned	Loss in cleaning	Quantity milled	Bran	Shorts
	Pounds	Pounds	Per cent	Pounds	Per cent	Per cent
Hard Red Springs, 1908	57.9	60.7	2.94	101.77	12.17	15.06
Hard Red Springs, 1909	56.4 56.6	59.2 59.8	2.5 2.3	125.7 115.0	12.0 11.9	16.1 16.9
Hard Red Springs, 1910	58.0 60.9	61.3 62.6	3.4 2.2	111.0 114.7	10.6 10.9	15.8 20.8
Durums, 1908	60.7	62.7	2.47	124.33	8.56	19.64
Durums, 1909	60.3	62.0	1.9	204.8	6.5	21.9
Durums, 1910	60.0	62.3	1.6	98.4	6.5	24.5

Class and Crop	Total flour	Loss in milling	Patent	1st Clear	2d Clear
	Pounds	Per cent	Pounds	Per cent	Per cent
Hard Red Springs, 1908	70.56	2.33	74.65	20.94	4.16
Hard Red Springs, 1909	68.6 68.5*	3.5 3.2	79.4 Milled as straight flour	18.3	2.5
Hard Red Springs, 1910	72.2 67.5*	2.6 2.3	74.2 Milled as straight flour	21.2	4.6
Durums, 1908	70.43	1.79	75.11	21.49	3.38
Durums, 1909	69.3	2.2	74.3	22.9	2.8
Durums, 1910	68.4	2.3	65.7	30.4	3.9

*Straight flour.

Table X. Averages of the Results of Baking Tests of Flours Milled from the Hard Red Spring and Durum Wheat Samples of the 1908, 1909 and 1910 Crops.

Class and Crop	Grade of flour	Per cent Water used	Grams Weights of loaf	Cc. Volume of loaf	Color
Hard Red Springs, 1908	Patents	54.2	479	2307	97
	1st Clears	55.4	489	2169	77.9
	2d Clears	57.4	497	1930	59.6
Hard Red Springs, 1909	Patents	51.7	477	2461	98
	1st Clears	54.0	485	2373	76
	2d Clears	55.6	488	1996	64
	Straights	51.6	478	2482	95.6
Hard Red Springs, 1910	Patents	52.0	481	2518	99.7
	1st Clears	53.2	489	2182	73.2
	2d Clears	53.9	495	1832	61.7
	Straights	52.3	478	2435	98.6
Durums, 1908	Patents	54.7	486	2166	92
	1st Clears	56.8	499	1971	77
	2d Clears	59.3	506	1747	66
Durums, 1909	Patents	51.9	457	2220	92
	1st Clears	54.0	483	1856	78
	2d Clears	57.3	502	1722	71
Durums, 1910	Patents	50.9	470	1898	92.9
	1st Clears	51.4	482	1698	80.0
	2d Clears	52.1	483	1471	62.5

Table XI. Averages of the Chemical Analysis of the Flours Milled from the Hard Red Spring and Durum Wheat Samples of the 1908, 1909 and 1910 Crops.

Class and Crop	Grade of flour	Moisture	Crude Protein Nx 6.25	Gliadin N x Nx 6.25	Gliadin No.	Ash	Acidity as lactic	Ether extract
		Per c.	Per c.	Per c.	Per c.	Per c.	Per c.	Per c.
Hard Red Springs, 1908	Patents	9.49	13.00	6.92	53.4	.496	.169	1.21
	1st Clears	9.24	14.31	7.17	50.6	.752	.277	1.64
	2d Clears	8.63	18.04	7.15	47.6	.903	.347	2.15
Hard Red Springs, 1909	Patents	11.46	14.26	7.87	55.3	.470	.159	1.06
	1st Clears	10.21	15.82	8.47	53.4	.760	.276	1.45
	2d Clears	10.34	15.88	8.38	51.6	.860	.318	1.67
	Straights	10.91	13.86	7.43	53.5	.550	.194	1.12
Hard Red Springs, 1910	Patents	11.26	14.34	7.94	53.5	.52	.142	----
	1st Clears	10.90	15.74	8.35	53.0	.72	.222	----
	2d Clears	10.19	16.45	8.15	49.7	.89	.301	----
	Straights	11.68	13.32	7.66	56.9	.54	.149	----
Durums, 1908	Patents	10.04	15.21	8.28	55.1	.687	.227	1.31
	1st Clears	9.66	16.62	8.78	53.1	.906	.317	1.82
	2d Clears	9.21	17.45	9.01	52.5	1.024	.357	2.13
Durums, 1909	Patents	11.08	15.49	8.84	56.8	.680	.206	1.15
	1st Clears	10.58	16.95	9.56	55.4	.960	.294	1.68
	2d Clears	9.84	17.92	9.91	54.9	1.050	.327	1.99
Durums, 1910	Patents	10.99	16.59	9.69	58.5	.70	.187	----
	1st Clears	10.53	17.70	10.08	57.0	.89	.277	----
	2d Clears	9.79	18.84	10.29	54.7	1.06	.314	----

There seemed to be less variation in the quality and composition of the hard spring wheat from the different sections of the State than is usually the case, with the exception of samples from Wheatland, Wahpeton, Grandin. Kindred, and Fargo in Cass County which were lower in gluten and baking strength than the average of the State. The results of the more important tests of the samples from these points are shown in,—

Table XII. Results of the more important tests made on the Hard Spring Wheat samples of the 1910 crop from Wahpeton, Wheatland, Grandin, Kindred and Fargo, Cass Co., N. D.

Sample Number	Source of Sample	Straight Flour	Water used	Volume of loaf	Color of loaf Crude Protein	N x 6.25
		Per cent	Per cent	Cc.		Per cent
596	Kindred	69.9	52.4	2310	99	12.00
610	Grandin	65.5	50.0	2400	102	12.06
611	Grandin	68.7	55.3	2310	100	10.81
612	Grandin	66.2	50.6	2380	102	10.81
613	Grandin	67.5	50.0	2420	98	12.38
713	Grandin	69.8	51.8	2380	97	12.75
626	Wheatland	62.2	49.7	2350	105	10.94
628	Wahpeton	75.6*	51.5	2310	100	10.94
629	Wahpeton	74.4	51.8	2260	99	13.00
712	Fargo	70.8	51.2	2230	96	12.75

*Total Flour.

The bearded spring or Velvet Chaff samples of the 1910 crop show the same variations in quality as did the samples of the 1909 crop. Sample No. 711 from Lisbon, N. D., contained 14.38% crude protein.
and gave a loaf volume of 2,650 cubic centimeters. Sample No. 712 raised in the vicinity of Fargo, gave a loaf volume of 2,230 cubic centimeters, and samples representing about every condition and quality between these two extremes were obtained. Considering the average of the six samples from Grandin as one sample we find the average of the Velvet Chaff wheats to be about equal to the average of the hard spring wheats as a class, so far as flour qualities are concerned, and such variations as occur are probably due to environment and general climatic conditions.

The hard spring samples of the 1910 crop, which were received at this laboratory, showed a range of from 11.38 per cent crude protein (from Wheatland, N. D.,) to 18.19 per cent crude protein (samples from Edgeley, and from New Salem, N. D.), a range of 6.81 per cent.

DURUM WHEATS.

Of the durum wheats, the Arnautka, Kubanka and Gharnovka varieties seem to be the most popular in those sections of the State which produce any considerable quantity of this class of wheat. So far as varieties are concerned, no pronounced difference in quality and composition between the varieties mentioned could be found that should not properly be attributed to the differences in conditions under which they were produced.

The durum wheats, as a class, present certain characteristics not possessed by any other class of wheat. The kernel is very hard and flinty, necessitating certain precautions in milling to produce flour of the best possible quality. It has occasionally happened that the damp or tough samples yielded flour of a higher quality than those samples which were relatively dry when they went to the rolls. Moreover, those samples which were wet with considerable water and allowed to stand for a unmber of hours, or even days, as a usual thing yielded flour of a higher quality than did the same wheats when not so treated. The conclusion seems justified therefore, that the tempering of these wheats is very important when it is desired to produce a flour for bread making purposes.

Tables XIII to XVIII, give in detail the results of tests of the durum wheats of the 1910 crop. A list is also included which shows the source and character of these samples. These samples all came from the Demonstration Farms and Sub-experiment Stations and were, therefore, milled into three grades of flour. Sample No. 607, "Coffee", wheat, from Dickinson, N. D., properly should not be included in this class, although it was selected from a plot of Kahla durum and is supposed to be field hybrid of Kahla with some other variety. "Jerusalem" and D. E. S. No. 488 are true durums, being selections from wheat of the same origin.

List of Durum wheat samples, crop of 1910, showing variety and source.

Sample No.	Variety	Source.
578	Arnautka	**Edgeley, N. D.
599	D. E. S. No. 488	**Dickinson, N. D.
605	Pelissier	**Dickinson, N. D.
606	Nicaragua	**Dickinson, N. D.
607	Coffee	**Dickinson, N. D.
608	Arnautka	**Dickinson, N. D.
609	Kubanka	**Dickinson, N. D.
627	Jerusalem, No. 287	**Dickinson, N. D.
640	Durum, Plot 1	*Carrington, N. D.
641	Durum, Plot 3	*Carrington, N. D.
642	Durum, Plot 4	*Carrington, N. D.
645	Wild Goose	*Carrington, N. D.
649	Durum, Plot 4	*Beach, N. D.
690	Arnautka	**Langdon, N. D.
710	Durum	*Hazelton, N. D.

*State Demonstration Farm.

**Agricultural Sub-Experiment Station.

Table XIII. Milling tests of the Durum Wheat samples, crop of 1910, which were separated into three grades of flours.

Sample Number	Wt. per bu. as rec'd	Wt. per bu. cleaned	Loss in cleaning	Quantity milled	Bran	Shorts	Total flour	Loss in milling	Total Flours Divided into:		
									Patent	1st clear	2d clear
	Pounds	Pounds	Per cent	Pounds	Per c ent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cnt
578	61.5	63.0	.9	117.50	2.9	33.6	62.8	.7	68.4	28.2	3.4
599	60.5	62.5	1.7	69.60	5.0	28.0	69.6	2.6	60.8	34.6	4.6
605	60	62.5	1.6	95.9	4.0	26.7	68.7	.6	63.0	34.1	2.9
606	60	62.5	1.6	62.1	7.6	22.6	67.2	2.6	61.1	34.1	4.8
607	60	62	1.1	100.17	17.0	19.4	60.0	3.6	66.1	30.6	3.3
608	61	63	1.5	91.60	4.9	25.3	72.3	a	61.7	34.5	3.8
609	61	64	1.7	134.8	4.9	22.7	71.4	1.0	65.5	31.7	2.8
627	60	62	2.2	69.8	6.5	32.0	62.3	b	57.4	39.4	3.2
640	60	62	2.3	107.10	4.7	24.4	72.8	c	70.9	27.2	1.9
641	60	63	1.5	110.75	6.3	24.2	67.9	d	80.2	17.7	2.1
642	60	62	1.9	106.8	5.7	23.0	72.2	e	71.5	25.3	3.2
645	60	63	2.2	57.6	5.2	22.6	72.3	f	69.2	27.6	3.2
649	62	64	.7	115.80	9.0	21.1	70.6	g	62.8	33.2	4.0
690	57	60	.8	120.85	5.1	21.5	70.3	3.1	69.2	25.6	5.2
710	57	60	2.2	115.25	9.2	20.0	66.3	4.5	58.7	31.6	9.7
Average	60	62.3	1.6	98.4	6.5	24.5	68.4	2.3	65.7	30.4	3.9

a—Gain of 2.5 per cent in milling
b—Gain of .8 per cent in milling
c—Gain of 1.9 per cent in milling
d—Gain of 1.6 per cent in milling
e—Gain of .9 per cent in milling
f—Gain of .1 per cent in milling
g—Gain of .7 per cent in milling

Table XIV. Moisture in the Durum Wheat samples—crop of 1910.

Sample number	Moisture in wheat before tempering per cent	Moisture in wheat after tempering per cent
578	12.9	11.0
599	12.8	14.0
605	12.5	13.4
606	12.2	14.8
607	12.2	12.7
608	12.0	13.5
609	11.6	12.8
627	11.3	13.0
640	11.6	14.6
641	11.4	13.3
642	10.3	13.3
645	12.0	12.6
649	11.8	14.0
690	16.1	16.2
710	16.3	16.6
Average	12.5	13.7

Table XV. Baking Tests of the flours milled from the Durum Wheat Samples—Crop of 1910.

Sample Number	Grade of flour	Water used	Wgt. of loaf	Volume of loaf	Color
		Per cent	Grams	Cubic	
578	Patent	52.9	475	1950	94
	1st Clear	50.9	485	1600	82
	2d Clear	52.9	491	1450	73
599	Patent	51.5	485	1680	85
	1st Clear	52.4	495	1560	79
	2d Clear	51.8	496	1530	67
605	Patent	52.9	485	2000	88
	1st Clear	53.2	488	1800	79
	2d Clear	56.2	492	1710	64
606	Patent	52.4	480	1880	82
	1st Clear	54.4	490	1690	76
	2d Clear	53.5	487	1530	64
607	Patent	51.5	480	2280	103
	1st Clear	51.8	476	2090	91
	2d Clear	50.6	481	1160	50
608	Patent	50.6	480	1870	85
	1st Clear	52.4	482	1730	82
	2d Clear	50.9	481	1380	57
609	Patent	51.2	478	2080	94
	1st Clear	50.0	478	1760	76
	2d Clear	----	---	----	--
627	Patent	49.1	465	1460	91
	1st Clear	51.2	468	1400	82
	2d Clear	51.5	483	1340	70
640	Patent	49.4	465	1800	94
	1st Clear	50.0	475	1550	76
	2d Clear	50.9	462	1450	57
641	Patent	51.8	470	1850	94
	1st Clear	50.9	483	1560	79
	2d Clear	52.1	465	1500	64
642	Patent	48.8	460	1790	99
	1st Clear	50.0	462	1530	70
	2d Clear	50.6	473	1380	57
645	Patent	48.2	474	1570	95
	1st Clear	50.0	483	1410	73
	2d Clear	51.5	485	1370	61
649	Patent	51.8	487	1940	91
	1st Clear	51.8	494	1680	85
	2d Clear	52.1	497	1650	67
690	Patent	50.3	476	2100	100
	1st Clear	51.5	484	1910	82
	2d Clear	----	---	----	--
710	Patent	51.2	478	2220	99
	1st Clear	51.2	489	2200	88
	2d Clear	----	---	----	--
Average	Patent	50.9	470	1898	92.9
	1st Clear	51.4	482	1698	80
	2d Clear	52.1	483	1471	62.5

Table XVI. Chemical Analysis of the Patent, First Clear and Second Clear flours milled from the Durum Wheat samples, crop of 1910.

Sample Number	Grade of flour	Moisture	Crude Protein	Gliadin N x 6.25	Gliadin No.	Ash	Acidity as lactic acid
		Per cent	Per cent	Per cent		Per ct.	Per ct.
578	Patent	10.69	18.13	10.69	58.9	.65	.207
	1st Clear	10.48	20.13	11.38	56.7	.91	.373
	2d Clear	9.86	20.38	11.19	54.9	.87	.360
599	Patent	11.46	16.81	10.31	61.3	.74	.234
	1st Clear	11.23	17.88	10.69	59.8	.92	.308
	2d Clear	10.27	18.38	10.06	54.8	.94	.308
605	Patent	11.09	16.38	9.06	55.4	.74	.180
	1st Clear	10.50	16.63	9.06	54.5	.77	.279
	2d Clear	9.88	17.00	9.25	54.4	.89	.304
606	Patent	11.29	16.75	10.50	62.7	.73	.144
	1st Clear	10.59	17.00	9.38	55.2	.81	.256
	2d Clear	10.66	18.75	9.81	52.3	1.04	.283
607	Patent	11.29	15.19	8.75	57.6	.43	.139
	1st Clear	11.04	16.81	10.13	60.2	.67	.225
	2d Clear	9.88	20.13	11.00	54.7	.88	.276
608	Patent	11.32	17.69	9.81	55.5	.82	.238
	1st Clear	10.43	16.63	11.06	66.6	.78	.202
	2d Clear	10.52	19.63	10.88	55.4	.95	.261
609	Patent	10.93	15.94	8.75	55.0	.66	.175
	1st Clear	10.61	16.31	8.69	53.2	.92	.259
	2d Clear	9.59	16.94	9.19	54.2	1.10	.297
627	Patent	10.52	17.86	9.88	55.2	.82	.157
	1st Clear	10.33	18.94	10.75	56.7	.98	.297
	2d Clear	9.52	19.44	10.81	55.7	1.10	.304
640	Patent	10.21	15.88	9.44	59.4	.65	.196
	1st Clear	10.07	16.88	10.06	59.7	.93	.319
	2d Clear	8.82	19.06	10.13	53.1	1.80	.366
641	Patent	10.74	16.44	10.06	61.2	.70	.178
	1st Clear	10.40	18.19	10.19	56.0	.76	.252
	2d Clear	9.62	18.94	10.69	56.4	.92	.290
642	Patent	10.54	17.25	10.19	59.0	.74	.225
	1st Clear	10.35	19.06	10.19	53.4	1.20	.353
	2d Clear	9.57	20.06	11.19	55.8	1.10	.394
645	Patent	10.46	18.56	10.88	58.6	.76	.238
	1st Clear	9.59	19.69	11.13	56.5	1.10	.373
	2d Clear	9.03	20.13	10.94	54.4	1.10	.375
649	Patent	11.84	13.81	8.94	64.7	.67	.162
	1st Clear	10.86	15.25	8.75	57.4	.75	.207
	2d Clear	10.37	15.75	9.63	61.1	.92	.306
690	Patent	11.11	17.31	9.63	55.6	.61	.139
	1st Clear	10.28	18.88	10.19	54.0	.84	.211
	2d Clear	9.34	19.44	9.75	50.1	1.10	.274
710	Patent	11.31	14.83	8.50	57.1	.82	.207
	1st Clear	11.26	17.25	9.56	55.4	.94	.245
	2d Clear	9.95	18.56	9.81	52.8	1.20	.306
Average	Patent	10.99	16.59	9.69	58.5	.70	.187
	1st Clear	10.53	17.70	10.08	57.0	.89	.277
	2d Clear	9.79	18.84	10.29	54.7	1.06	.314

Table XVII. Crude Protein in Wheat.

Sample Number	Crude Protein in wheat N x 6.25	Sample Number	Crude Protein in wheat N x 6.25
	Per cent		Per rent
578	20.31	640	18.13
599	18.38	641	17.50
605	16.94	642	18.19
606	18.19	645	18.75
607	19.31	649	15.31
608	18.25	690	18.44
609	15.94	710	17.13
627	19.00	Average	17.98

Table XVIII. Results of the more important tests made on the Durum wheat samples, crop of 1910, which were separated into three grades of flour.

			TESTS ON PATENT FLOUR			
Sample Number	**Total flour**	**Patent flour**	**Water used**	**Volume of loaf**	**Color of loaf**	**Crude Protein N x 6.25**
	Per cent	Per cent	Per cent	Cc.		Per cent
578	62.8	68.4	52.9	1950	94	18.13
599	69.6	60.8	51.5	1680	85	16.81
605	68.7	63.0	52.9	2000	88	16.38
606	67.2	61.1	52.4	1880	82	16.75
607	60.0	66.1	51.5	2280	103	15.19
608	72.3	61.7	50.6	1870	85	17.69
609	71.4	65.5	51.2	2080	94	15.94
627	62.3	57.4	49.1	1460	91	17.86
640	72.8	70.9	49.4	1800	94	15.88
641	67.9	80.2	51.8	1850	94	16.44
642	72.2	71.5	48.8	1790	99	17.25
645	72.3	69.2	48.2	1570	95	18.56
649	70.6	62.8	51.8	1940	91	13.81
690	70.3	69.2	50.3	2100	100	17.31
710	66.3	58.7	51.2	2220	99	14.88
Average	68.4	65.8	50.9	1898	92.9	16.59

OTHER VARIETIES.

A number of samples of varieties which could not properly be classified under either the hard spring or durum wheat groups were received during the year. The results of the tests of these samples are shown in tables XIX to XXIII. Samples Nos. 601, (Summer), 603 (Yakutsk), and 604 (Ghirka,) were semi-hard spring wheats. None of these yielded very high percentages of flour nor were the flour qualities particularly good, with the exception of the Ghirka, in spite of the fact that they contained fairly high percentages of crude protein. The Ghirka, however, gave very good results when baked, as it has done in previous years.

Samples Nos. 615, 651, and 714, were Turkey type hard red winter wheats from Amenia, New Salem and Grandin respectively. All three samples yielded fairly high percentages of flour, but the flour produced from No. 651 from New Salem was quite outstanding in point of quality, as evidenced by the color and loaf volume when baked.

Samples Nos. 709, Argentina from Glasston, N. D., and 718, Alaska from Anselm, N. D., were soft spring wheats, both of which were very poor so far as baking qualities are concerned. The Alaska sample appeared to be rather immature, which may in a measure be responsible for the rather small loaf volume and low color score. In fact none of the Alaska samples, which have been received at this laboratory from time to time, have been wholly ripe or mature.

List of Other Varieties of wheat, crop of 1910, showing variety and source.

Sample No.	Variety	Source.
601	Summer. No. 2949 B, semi-hard, bearded spring wheat	**Dickinson, N. D.
603	Yakutsk. smooth chaff semi-hard spring wheat,	**Dickinson, N. D.
604	Chirka, semi-hard spring	**Dickinson, N. D.
615	Turkey Red winter	Amenia, N. D.
651	Hard red winter	*New Salem, N. D.
709	Argentina. soft red wheat	Glasston, N. D.
714	Hard red winter	Grandin, N. D.
718	"Alaska", soft white wheat	Anselm, N. D.

*State Demonstration Farm.
**Agricultural Sub-Experiment Station.

Table XIX. Milling tests of the Other Varieties of wheat—Crop of 1910.

Sample Number	Wgt. per bu. rec'd	Wgt. per bu. cleaned	Loss in cleaning	Quantity milled	Bran	Shorts
	Pounds	Pounds	Per cent	Pounds	Per cent	Per cent
601	56	60	2.4	90.5	13.0	18.8
603	55	60	4.3	63.80	10.3	25.1
604	61	62.5	1.2	131.60	8.7	23.4
651	60	61	2.6	114.80	9.1	21.7
615	64	66	.3	116.90	8.2	21.1
709	51	56	4.3	37.73	15.2	18.9
714	59	62.5	2.6	113.22	9.9	17.6
718	53	56	2.6	110.5	4.5	24.0

Sample Number	Total flour	Loss in milling	Patent	1st Clear	2d Clear
	Per cent	Per cent	Per cent	Per cent	Per cent
601	64.6	3.6	68.3	27.7	4.0
603	67.4	2.8	67.3	29.8	2.9
604	63.4	4.5	64.5	32.1	3.4
651	70.0	a	63.3	33.4	3.3
615	*71.4	b	Milled as straight flour		
709	*55.7	10.2	Milled as straight flour		
714	*70.2	2.3	Milled as straight flour		
718	*71.5	.9	Milled as straight flour		

*Straight flour.

a—Gain of .8 per cent in milling
b—Gain of .7 per cent in milling

Table XX. Moisture in the Other Varieties of wheat—Crop of 1910.

Sample number	Moisture in wheat before tempering per cent	Moisture in wheat after tempering per cent
601	12.8	14.4
603	12.7	13.7
604	13.4	14.3
615	12.0	12.8
651	13.8	15.4
709	15.4	16.0
714	13.1	13.5
718	11.3	12.8
Average	13.1	14.1

Table XXI. Baking Tests of the Flours Milled from the Other Varieties of Wheat—Crop of 1910.

Sample Number	Grade of flour	Water used	Wgt. of loaf	Volume of loaf	Color
		Per cent	Grams	Cubic	
601	Patent	48.5	497	2250	97
	1st Clear	50.6	487	1850	61
	2d Clear	50.0	485	1600	50
603	Patent	48.5	481	2100	96
	1st Clear	50.6	483	1850	61
	2d Clear	----	---	----	--
604	Patent	51.2	475	2460	100
	1st Clear	51.5	483	2100	94
	2d Clear	52.1	487	1600	64
615	Straight	49.1	472	1950	91
651	Patent	51.2	483	2450	98
	1st Clear	52.9	490	2130	85
	2d Clear	53.5	491	1900	70
709	Straight	48.2	475	2050	95
714	Straight	52.4	481	2370	91
718	Straight	51.5	487	1850	73

Table XXII. Chemical Analysis of the Flours Milled from the Other Varieties of wheat—Crop of 1910.

Sample Number	Grade of flour	Moisture	Crude Protein N x 6.25	Gliadin N x 6.25	Gliadin No.	Ash	Acidity as lactic acid
		Per cent	Per cent	Per cent		Per ct.	Per cent
601	Patent	11.15	14.88	8.88	59.6	.47	.135
	1st Clear	11.29	16.25	9.44	58.1	.65	.205
	2d Clear	11.54	18.19	9.18	50.5	.85	.301
603	Patent	10.88	15.00	8.00	53.4	.47	.135
	1st Clear	10.67	16.44	9.13	55.5	.62	.225
	2d Clear	10.10	18.69	9.81	52.5	.78	.304
604	Patent	11.51	11.81	7.50	63.5	.47	.139
	1st Clear	11.56	15.00	7.88	52.5	.68	.157
	2d Clear	10.56	17.00	8.25	48.5	.82	.272
615	Straight	11.39	11.13	6.13	55.1	.54	.124
651	Patent	11.81	14.13	8.56	55.9	.50	.177
	1st Clear	10.96	15.31	8.63	56.3	.62	.252
	2d Clear	10.37	15.50	8.69	56.0	.67	.292
709	Straight	10.20	13.75	7.88	57.3	.68	.128
714	Straight	10.87	14.19	8.06	56.8	.60	.126
718	Straight	9.59	14.63	7.13	48.7	---	.213

Table XXIII. Crude Protein in Wheat

Sample number	Crude Protein in wheat N x 6.25 per cent
601	17.13
603	17.63
604	15.50
615	11.94
651	16.75
709	12.50
714	15.06
718	15.38
Average	15.24

TESTS ON THE SMALL TWO STAND EXPERIMENTAL MILL.

The samples were first cleaned and scoured, and were then tempered by adding measured amounts of water to the wheat in a pan, which was thoroughly mixed and the pan covered and allowed to stand for a time; usually sixteen to twenty hours in the case of the hard wheats. By a system of re-grinds each sample was subjected to five breaks and from seven to nine reductions, all the flour streams being combined to form a straight flour until the quality of the material produced was too poor for flour of this grade, when the remaining tailings stock was sent to shorts. Three products were obtained from the samples ground in this way, viz., straight flour, shorts and low grade, and bran.

Samples Nos. 17A to 23A were bearded spring or Velvet Chaff wheats grown on the experiment station farm at Fargo, N. D., and represented several varieties and strains of seed from different sources. As will be noted there was considerable variation in the quality of these samples, Nos. 17A, 18A, 19A and 20A, giving much better results when baked than did No. 21A, which was grown from a strain commonly known as "humpback" or "Bearded Bluestem", the seed of which came from near Kensington, Minn., while the Velvet Chaff grown from seed obtained from Renville, Minn., No. 23A, occupied about an intermediate position with respect to flour quality. Several of these Velvet Chaff samples were possessed of baking qualities slightly superior to the selected strain of Haynes Bluestem grown on the same farm, No. 24A.

Nos. 28A to 33A inclusive, were samples which constituted a series of co-operative tests, and were submitted by the American Society of Milling and Baking Technology. A number of other investigators and experienced wheat and flour testers have made tests of the samples, and it is hoped by this means to ultimately unify testing practices.

Nos. 35A to 48A inclusive, were samples from plots on the Experiment Station Farm at Fargo, N. D. The three bearded Spring or Velvet Chaff samples Nos. 38A, 39A and 40A. were of remarkably good quality, both in the yield of flour and its baking qualities. Nos. 49A and 50A, were samples raised in the vicinity of Lisbon, N. D., and the Velvet Chaff sample appeared to be slightly superior to the hard spring wheat sample No. 49A, which was apparently largely Bluestem wheat, although the differences between the two were very slight indeed.

Tables XXIV and XXV, show the results of the milling and baking tests of the samples milled on a small two stand experimental mill.

List of samples milled on the small, two-stand experimental roller mill, showing variety and source.

No. Sample	Variety	Source.
A1	Bluestem	Larimore, N. D.
A2	Bluestem, from corn ground	Wahpeton, N. D.
A3	Bluestem, from oat ground	Wahpeton, N. D.
A4	Fife	Portland Junction, N. D.
A5	Ghirka	Dickinson, N. D.
A6	Fife	Hettinger, N. D.
A7	Fife	Williston, N. D.
A8	Bluestem	Jamestown, N. D.
A9	Fife	Hoople, N. D.
A10	Fife	Langdon, N. D.
A11-15	Bluestem	Wahpeton, N. D.
A16	Fife	Carrington, N. D.
A17	Worlds Beater,	Agricultural College, Fargo, N. D.
A18	Dakota Climax (bearded spring)	Agricultural College, Fargo, N. D.
A19	Dakota Climax	Agricultural College, Fargo, N. D.
A20	Velvet Chaff	Agricultural College, Fargo, N. D.
A21	Bearded (Humpback) spring	Agricultural College, Fargo, N. D.
A22	Bearded spring, seed from Redfield, S. D.	Agricultural College, Fargo, N. D.
A23	Bearded spring, seed from Renville, Minn.	Agricultural College, Fargo, N. D.
A24	Haynes Bluestem	Agricultural College, Fargo, N. D.
A25	Hard spring wheat	Starkweather, N. D.
A26		Fargo, N. D.

A27	Bluestem	Moreton, N. D.
A28	Red Fife, Co-operative tests	Ottawa, Canada.
A29	Preston, Co-operative tests	Ottawa, Canada.
A30	Hard winter, Co-operative tests	Manhattan, Kansas.
A31	Soft red winter, Co-operative tests	Manhattan, Kansas.
A32	Minn. 169, Bluestem, Co-operative tests	St. Anthony Park, Minn.
A33	Arnautka, Durum, Co-operative tests	Edgeley, N. D.
A34	Soft red winter	Owensboro, Ky.
A35	Durum, Arnautka type	Agr. College, Fargo, N. D.
A36	Durum, Arnautka type	Agr. College, Fargo, N. D.
A37	Durum, Arnautka type	Agr. College, Fargo, N. D.
A38	Bearded spring, Velvet Chaff type	Agr. College, Fargo, N. D.
A39	Bearded spring, Velvet Chaff type	Agr. College, Fargo, N. D.
A40	Bearded spring, Velvet Chaff type	Agr. College, Fargo, N. D.
A41	Increase of White Durum Individual	Agr. College, Fargo, N. D.
A42	Increase of Large red berried durum	Agr. College, Fargo, N. D.
A43	Increase of white berried durum	Agr. College, Fargo, N. D.
A44	Increase of red berried durum	Agr. College, Fargo, N. D.
A45	Increase of large white berried durum	Agr. College, Fargo, N. D.
A46	Increase of red berried durum	Agr. College, Fargo, N. D.
A47	Increase of durum individual	Agr. College, Fargo, N. D.
A48	Durum, Arnautka type	Agr. College, Fargo, N. D.
A49	Hard red spring	Bemmels Mill, Lisbon, N. D.
A50	Velvet Chaff	Bemmels Mill, Lisbon, N. D.

Table XXIV. Milling tests of the wheat milled on the small mill, crop of 1910.

Sample No.	Wgt. per bu. as rec'd	Wgt. per bu. as cleaned	Loss in cleaning	Quantity milled	Bran	Shorts and low grade	Straight flour	Loss in milling
	Pounds	Pounds	Per cent	Grams	Per cent	Per cent	Per cent	Per c.
1A	59	62	0.0	2127	8.0	22.4	70.6	0.0
2A	59	63	0.0	1161	8.5	17.7	67.2	6.6
3A	61	64	0.0	1139	8.7	17.5	66.6	7.2
4A	61	64	0.0	2182	10.5	15.7	68.6	5.2
5A	60	63	0.0	2177	13.0	22.1	59.9	5.0
6A	54	58	0.0	2141	10.9	25.0	62.2	1.9
7A	61	63	0.0	2155	7.9	16.3	72.4	3.4
8A	56	61	0.0	2146	8.6	17.0	71.4	3.0
9A	61	64	0.0	2132	11.3	16.8	70.5	1.4
10A	59	63	0.0	2141 p	10.2	15.8	71.5	2.5
11A	59	60.5	---	2191	5.8	25.1	66.7	2.4
12A	58.5	60.5	---	2164	14.4	17.6	67.8	.2
13A	59	59	---	2173	11.1	20.8	71.2	3.1
14A	59	61	---	2168	11.1	19.6	72.0	2.7
15A	58.5	61	---	2168	11.0	19.5	72.0	2.5
16A	60	60.5	0.0	2146	11.5	14.1	72.0	2.4
17A	60	60	0.0	2109	13.1	14.3	71.8	.8
18A	61	62.5	0.0	2173	11.7	18.1	67.5	2.7
19A	63	63	0.0	2168	11.8	15.4	70.3	2.5
20A	63.5	63	0.0	2204	12.2	18.0	69.2	2.6
21A	58.5	59	0.0	2059	10.6	15.9	70.9	2.6
22A	63.5	63.5	0.0	2050	12.1	14.2	71.2	2.5
23A	62.5	62.5	0.0	2136	11.3	14.3	72.0	---
24A	59	60	0.0	2141	10.3	15.0	72.2	2.5
25A	59	63	---	1946	13.8	13.5	67.8	4.9
26A	59	60.5	---	1975	8.5	19.2	70.4	1.9
27A	59	62	---	1950	10.2	18.1	69.2	2.5
28A	62	65	1.1	2000	13.1	11.3	71.4	4.2
29A	62	65	.9	2000	11.4	14.3	71.3	3.0
30A	61.5	64.5	1.3	1782	12.1	14.2	71.7	2.0
31A	61	64	2.9	1919	9.9	13.9	70.8	5.4
32A	59	62	1.1	2000	10.5	17.2	70.0	2.3
33A	61	64	1.9	2000	8.4	18.7	70.8	2.1
34A	60.5	62	3.1	2000	9.2	16.4	68.4	6.0
35A	62.5	64	1.8	2001	8.0	21.0	70.4	.6
36A	61.5	63.5	1.8	2001	10.4	18.7	70.1	.8
37A	62.5	64	2.4	2000	8.9	19.0	71.9	.2
38A	64	65.5	1.2	2000	16.4	11.2	72.5	.10
39A	63	65	3.0	2000	14.0	14.2	71.0	.8
40A	63	65	.4	2000	10.8	16.2	71.7	1.3
41A	62.5	64	2.1	2001	7.7	19.1	72.0	1.2
42A	62	63.5	2.7	2000	10.6	18.3	69.3	1.8
43A	63.5	64	2.1	2000	12.0	16.95	71.0	.05
44A	63.5	63.5	1.6	2000	13.2	17.6	69.1	.1
45A	62.5	63.5	3.5	2000	14.1	13.6	71.5	.8
46A	63	64.25	1.7	2000	11.4	16.3	71.0	1.3
47A	63.25	63.5	2.6	2000	9.7	18.1	70.0	2.2
48A	63	64.25	2.0	1990	11.1	14.7	74.0	.2
49A	60	62	---	2000	13.7	15.3	69.4	1.6
50A	59	62.5	---	2000	11.8	16.9	70.2	1.1

Table XXV. Baking tests of the wheat milled on the small mill, crop of 1910.

Sample Number	Grade of flour	Water used	Wgt. of loaf	Volume of loaf	Color
		Per cent	Grams	Cubic cm.	
1A	Straight	54.1	482	2650	94
2A	Straight	53.8	486	2420	94
3A	Straight	52.4	482	2450	94
4A	Straight	53.5	484	2450	93
5A	Straight	54.7	486	2490	93
6A	Straight	55.3	485	2410	95
7A	Straight	56.8	489	2410	98
8A	Straight p	55.0	485	2430	98
9A	Straight	54.1	487	2310	99
10A	Straight	55.6	485	2450	97
11A	Straight	52.1	472	2380	Dirty
12A	Straight	51.2	476	2370	95
13A	Straight	51.8	474	2360	96
14A	Straight p	51.5	475	2320	98
15A	Straight	51.2	474	2350	98
16A	Straight	55.0	483	2520	101
17A	Straight	53.5	482	2440	99
18A	Straight	51.5	476	2430	102
19A	Straight	50.9	478	2490	105
20A	Straight	50.0	475	2450	100
21A	Straight	50.0	476	2240	95
22A	Straight	50.0	475	2360	98
23A	Straight	50.0	476	2310	97
24A	Straight	51.8	480	2410	98
25A	Straight	55.6	490	2710	99
26A	Straight	51.5	481	2430	99
27A	Straight	54.4	489	2220	94
28A	Straight	53.2	477	2760	99
29A	Straight	52.1	485	2200	95
30A	Straight	51.2	483	2310	101
31A	Straight	51.8	482	2390	100
32A	Straight	52.4	477	2560	100
33A	Straight	50.6	480	2020	94
34A	Straight	48.2	471	2200	100
35A	Straight	51.2	482	1780	88
36A	Straight	50.9	481	1800	88
37A	Straight	51.2	479	1900	91
38A	Straight	53.5	478	2770	101
39A	Straight	54.1	479	2750	102
40A	Straight	53.2	480	2620	100
41A	Straight	50.9	482	1770	88
42A	Straight	52.4	478	1810	85
43A	Straight	50.3	470	1860	91
44A	Straight	51.2	475	1640	85
45A	Straight	50.3	468	2100	94
46A	Straight	51.2	476	1710	88
47A	Straight	50.9	476	1590	85
48A	Straight	50.3	471	1960	91
49A	Straight	52.6	477	2620	101
50A	Straight	52.4	475	2660	102

CRUDE PROTEIN CONTENT OF HARD SPRING AND DURUM WHEATS RAISED ON THE SAME FARM DURING SEVERAL SUCCESSIVE YEARS.

In Table XXVI is shown the per cent of crude protein in the hard spring wheats of the 1907, 1908, 1909, 1910 crops from eleven points in the State. The data was so incomplete that it did not appear advisable to average the samples of the several years, but on studying the table some very interesting things are to be found. In the first place, certain localities have invariably produced wheats high in protein, while the wheats from other localities have been comparatively low in this respect. The range in protein content when grown on the same farm in different years, in certain instances amounts to over six per cent and very frequently from four to five per cent. This Table also shows that there is less difference from year to year in certain localities than in others, the greatest variation, being found in those counties bordering on the Red River in the eastern sections of the State.

Table XXVI. Percent of Crude Protein (N X 6.25) in the Hard Spring Wheats of the 1907, 1908, 1909 and 1910 crops from various points.

Source of Sample	Crude Protein (N x 6.25) in wheats.			
	1907	1908	1909	1910
	Per cent	Per cent	Per cent	Per cent
Bathgate	-----	12.06	13.62	13.94
	-----	10.63	13.69	-----
Dickinson	-----	18.31	16.47	16.63
	-----	-----	15.93	18.13
	-----	-----	16.25	-----
Edgeley	15.50	19.06	17.74	18.19
	-----	18.19	18.06	16.94
Grove	-----	17.50	20.53	-----
Lakota	12.50	16.81	15.69	16.25
Langdon	-----	-----	14.38	16.38
	-----	-----	15.12	16.63
Larimore	-----	11.38	12.06	15.31
	-----	10.31	11.81	16.44
New Salem	13.62	17.38	13.72	18.19
Page	11.25	13.63	16.06	15.31
Rugby	-----	-----	15.72	17.06
Sanborn	11.87	15.88	-----	16.81

Table XXVII shows the per cent of crude protein in the durum wheats of the 1907, 1908, 1909, 1910 crops from eleven different farms. As in the case of the hard springs we find considerable range in protein content in different seasons. Another interesting fact, brought out very clearly in this table, is that a considerable range in the composition of wheat of the same general class raised on a farm, during the same season, is frequently found. This difference in per cent of crude protein in some cases amounts to over four per cent, although such wide differences are not usually met with.

Table XXVII. Percent of Crude Protein (N X 6.25) in the Durum Wheats of the 1907, 1908, 1909 and 1910 crops from various points.

Source of Sample	Crude Protein (N x 6.25) in wheats.			
	1907	1908	1909	1910
	Per cent	Per cent	Per cent	Per cent
Beach	11.75	14.44	15.44	15.31
	-----	13.81	15.72	-----
	-----	16.75	-----	-----
Carrington	-----	15.19	16.94	18.13
	-----	14.88	17.41	17.50
	-----	-----	15.34	18.19
Dickinson	14.37	18.00	17.13	18.38
	-----	16.44	16.19	16.94
	-----	19.00	-----	18.19
	-----	-----	-----	18.25
	-----	-----	-----	15.94
	-----	-----	-----	19.00
Edgeley	13.94	18.50	15.38	20.31
	12.27	19.94	19.69	-----
	14.81	18.19	16.19	-----
	-----	17.25	16.63	-----
Flaxton	-----	17.06	17.84	-----
	-----	17.94	18.06	-----
Granville	11.19	13.94	15.25	-----
Hazelton	-----	-----	15.81	17.13
Langdon	-----	-----	15.13	18.44
New Salem	11.37	15.69	13.72	-----
Ross	-----	19.94	19.63	-----
Williston	-----	16.63	15.75	-----

Since the crude protein content of durum wheat as a class, has been found to be somewhat higher than the hard spring wheats, the average difference in some crops amounting to about 2.5%, it appeared advisable to ascertain whether or not this difference was due to an inherent tendency on the part of the durums to contain more crude protein than the hard spring wheats when grown under the same conditions.

Table XXVIII shows the per cent of crude protein in the hard red spring and durum wheats when grown on the same farm for several successive years, and reveals the fact that in about half of the cases the durum wheat was lower in protein content, while the average of the eleven comparisons cited showed little or no difference in this respect. The conclusion, therefore, seems justified that the high protein content of the durum wheat as a class is due to the fact that the bulk of this wheat is grown under conditions which favor the production of wheat high in protein, and not to any pronounced tendency of the durum wheats to contain more total protein.

Table XXVIII. Crude Protein in Hard Spring and Durum Wheat when grown on the same farm.

Source	Year	Hard Spring per cent	Durum per cent
Dickinson	1909	15.93	17.61
	1910	17.38	17.78
Edgeley	1907	15.50	13.67
	1908	18.62	18.47
	1909	18.12	16.97
	1910	17.57	20.31
Langdon	1909	14.75	15.13
	1910	16.50	18.44
New Salem	1907	13.62	11.37
	1908	17.38	15.69
	1909	14.66	13.72
Average		16.37	16.29

RELATION BETWEEN CRUDE PROTEIN IN WHEAT AND THE BY-PRODUCTS OR FEEDS PRODUCED IN MILLING.

In order to ascertain how much effect the composition of the original wheat had upon the composition of the feeds, as produced in the experimental mill at the North Dakota Agricultural Experiment Station, the protein content of all hard wheats tested has been compared with the protein content of the bran and shorts produced. The results of these comparisons are given in table XXIX, which shows that on the average the crude protein in the feed increases uniformly with the crude protein in the wheat used, and is higher in actual per cent. It is true that the general rule does not hold good in every case, but there are not very many, nor particularly wide variations from the general average. Nor should these figures be taken to show exactly what per cent of crude protein there will be in the feeds produced in any mill from wheat of a known protein content, as much depends upon how the feeds are produced and of what streams they are composed. It simply serves to show the usual relationship between the composition of the raw material and the by-products in milling, when the same system of milling is followed in all cases and the same general type of wheat is used. Since we have found a range of from 10.31 per cent to 20.53 per cent in the crude protein content of the hard spring wheats of North Dakota, it is very evident that a considerable range in the protein content and feeding value of the mill feeds produced from wheats grown in the State is to be expected.

Table XXIX. Relation between the Protein Content of Wheat and Foods produced therefrom.

Average in wheat N x 6.25	Average in bran N x 6.25	Average in shorts N x 6.25
11.0	12.7	15.5
13.2	14.9	17.0
15.4	17.0	19.4
17.8	18.9	21.2

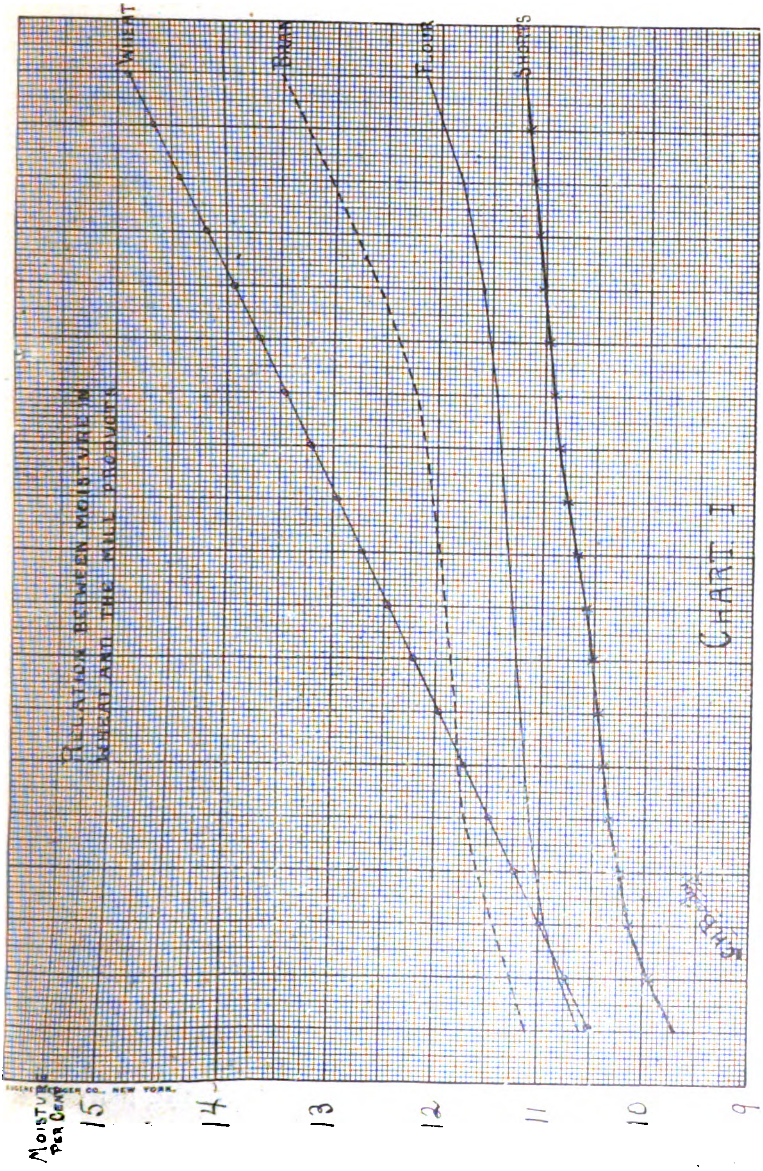
LOSS IN MILLING.

A problem that is frequently puzzling to the miller is the matter of invisible loss in milling. In this investigation it was discovered that only a portion of the loss was caused by the sifting of material through cracks and aperatures in the spouting and machinery, or what could be termed "mechanical loss", but that evaporation of moisture was apparently responsible in large measure for the very considerable losses that frequently occurred. Table XXX gives the average per cent of moisture in wheats of varying moisture content and of the several mill products. This shows that considerable loss must frequently occur through evaporation, since in very few cases did the moisture in any of the products exceed that in the wheat from which they were produced, and in most cases it was decidedly less.

Table XXX. Moisture in wheat and mill products produced therefrom.

Moisture in wheat	Moisture in flour	Moisture in bran	Moisture in shorts
	Per cent	Per cent	Per cent
10.5	10.6	11.1	9.7
11.2	11.1	11.6	10.4
11.8	11.1	11.7	10.2
12.1	11.0	11.8	10.5
12.75	11.1	11.7	10.3
13.2	11.2	11.8	10.4
13.6	11.35	12.2	10.5
14.4	12.0	12.9	10.7
15.9	12.2	13.5	11.15

The relationship between the moisture content of wheat before tempering, and the several mill products is shown graphically in Chart I, which was prepared from the foregoing table, applying the proper mathematical formulae for laying out the curves. This shows that the moisture content of the products does not parallel that of the wheat, the loss thru evaporation being greater when the per cent of moisture in the wheat is high.


Relation between Moisture in Wheat and the Mill Products
Wheat
Bran
Flour
Shorts
Chart I
SHB
Moisture Per Cent
15
14
13
12
11
10
9
Eugene Dietzgen Co., New York.

CAUSE OF VARIATIONS IN THE LOSS IN MILLING

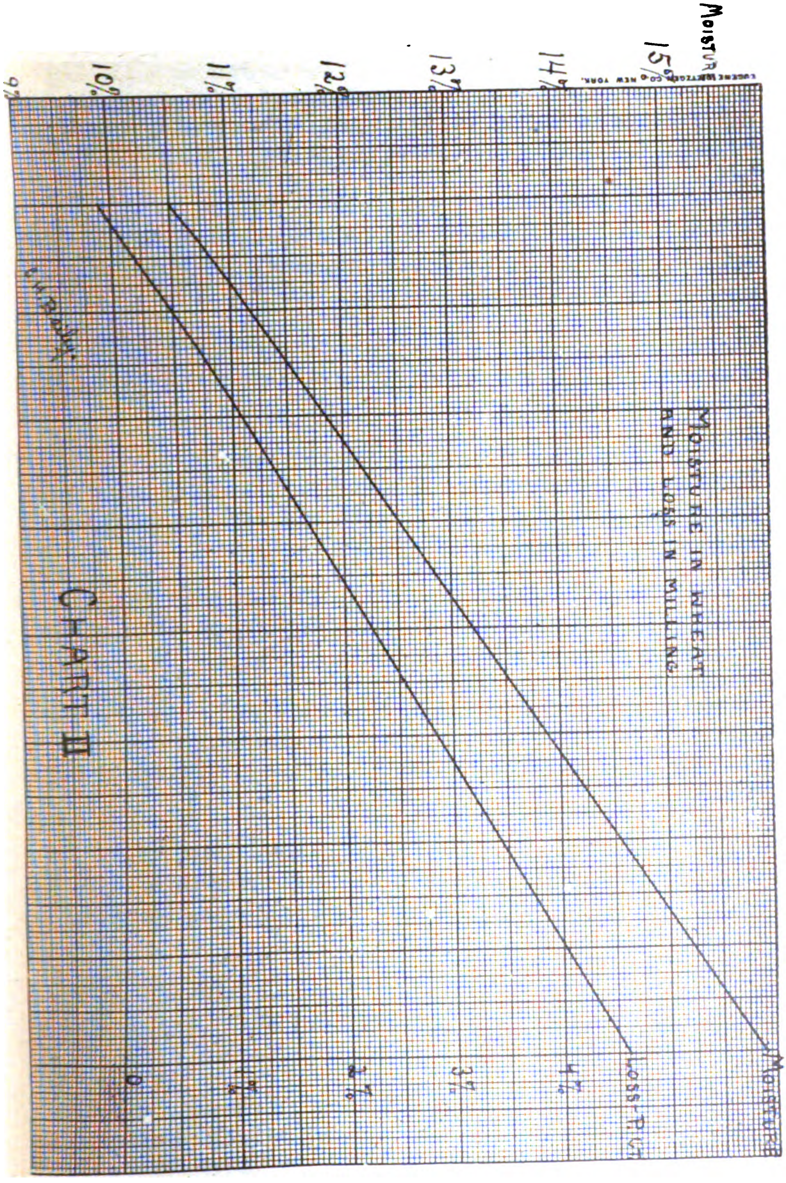
In order to ascertain what factors were principally responsible for the rather wide ranges in loss that occurred by this means, a study was made in working with a large number of hard wheat samples. And while it was found that several factors effected the amount of loss, such as the temperature of the rolls, ease of reduction, length of the milling system, humidity of the atmosphere, etc., the one particular factor that seemed to be principally responsible for the variations was the moisture content of the clean wheat before tempering. When the moisture content was low, the loss thru evaporation was invariably small, and when the moisture was high, the quantity of water lost thru evaporation was without exception large in amount. Table XXXI shows the loss of moisture in milling in working with wheats of varying moisture content.

Table XXXI. Relation between the moisture content of the wheat before tempering and the loss of moisture in milling.

Moisture in Wheat	Loss of Moisture in Milling per 100 lbs.
Percent	Pounds
10.5	.07*
11.2	.13
11.8	.98
12.1	1.49
12.75	1.95
13.2	2.33
13.6	2.72
14.4	2.92
15.9	4.53

*Gain.

Chart II, based on the above table, shows graphically the relationship between the per cent of moisture in the wheat before tempering, and the loss in milling due to evaporation. The amount of loss in this way runs parallel to the moisture content of the wheat, and ranges from a slight gain due to added water in tempering, when the per cent of moisture in the wheats averaged 10.5%, to an average loss of over 4.5% when the wheat contained about 16% moisture before tempering.


MOISTURE IN WHEAT
AND LOSS IN MILLING
CHART II
C. H. Bailey
Moisture
9%
10%
11%
12%
13%
14%
15%
EUGENE DIETZGEN CO. NEW YORK.
0
1%
2%
3%
4%
Loss-P'c't
Moisture

SUMMARY.

1. The production of wheat per square mile in 1909 was greatest in Bottineau, LaMoure, Steele and Nelson counties, and the eastern sections of the State. (Map No. 1, Page 204.)

2. The production of Durum wheat per square mile in 1909 was greatest in LaMoure, Ransom, and Sargent counties. (Map No. 2, Page 205.)

3. The proportion of durum wheat produced in 1909 was greatest in Ransom, Sargent and Dickey counties. (Map No. 3, Page 206.)

4. The average quality of the hard spring wheat of the 1910 crop was superior, both in the yield of flour and in the gluten content and baking strength of flour, to the 1908 and 1909 crops. (Tables IX, X and XI.)

5. The average quality of the 1910 durum wheats was somewhat inferior to the two preceding crops. (Tables IX, X, and XI.)

6. The bearded spring or "Velvet Chaff" wheats, when dry and well cured, compared very favorably with other hard spring wheats raised in the same localities. (Tables VII and VIII.)

7. The small two-stand experimental mill, when properly handled, will produce flours which indicate relative baking qualities, but does not give accurate quantitative milling yields.

8. The durum wheats do not necessarily contain more crude protein and gluten than the hard spring wheats, when raised under the same conditions. (Table XXVIII.)

9. The composition and feeding value of the by-products or feeds, as a usual thing, bears a distinct relation to the composition of the wheats from which produced, being higher in protein when produced from high protein wheats, and

lower in protein when low protein wheats are used. (Table XXIX.)

10. The moisture content of flours and feeds depends to a large extent on the moisture content of the wheat before tempering, when the same method of milling is followed in all cases.

11. With wheats of the same general type the loss in milling due to evaporation runs approximately parallel to and increases with the moisture content of the wheat before tempering, when the same method of milling is employed. (Table XXXI and Chart II.)

North Dakota Agricultural College

GOVERNMENT AGRICULTURAL
EXPERIMENT STATION
OF NORTH DAKOTA

BULLETIN NUMBER 94

Swamp Fever in Horses

By L. Van Es, E. D. Harris and A. F. Schalk

Any farmer, teacher, or student in the State may have this Bulletin mailed
to his address, free of charge, upon application.

FARGO. NORTH DAKOTA, U. S. A.
SEPTEMBER, 1911

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SWAMP FEVER IN HORSES

(From Department of Veterinary Science.)

ERRATA

Page 264: Line 6 read “seemed” instead of “seemd.”
Page 266: Line 3 read “be” instead of “the.”
Page 272: Line 30 read “of” instead of “or.”
Page 279: Line 13 read “an emaciated” instead of “enemaciated.”
Page 282: Line 37 read “is” instead of “in.”
Page 289: Line 6 read “cadaver instead of “cavader.”
Page 289: Line 33 read “cadaver” instead of “cavader.”
Page 293: Line 35 read “cadaver” instead of “cavader.”
Page 296: Line 8 read “marked” instead of “naked.”
Page 296: Line 26 read “ulceration” instead of “ulcertation.”
Page 297: Line 7 read “is” instead of “are.”
Page 297: Line 35 read “cadaver” instead of “cavader.”
Page 300: Line 24 read “no” instead of “not.”
Page 311: Line 27 read “remittant” instead of “resistant.”
Page 312: Line 11 insert “with” after “lessens.”
Page 333: Line 19 read “disturbance” instead of “disturbances.”
Page 343: Line 3 read “638” instead of “618.”
Page 351: Line 2 insert “of” after “transmissions.”

large area of Manitoba and into some parts of the Northwest territories.

A disease, of which it is fair to suppose that it is identical with “swamp-fever” is described by Watson (6), who writing in 1896, states that the disorder first made its appearance in the vicinity of Eau Claire in the State of Wisconsin some seven or eight years before. Since then it had continued its distribution covering an area with a radius of about one hundred miles.

In 1899 Taylor (7) describes the Manitoba disease, but it was not until 1902 that a full scientific description of the disease was offered by Torrance (9).

In addition to the published reports of Torrance (9-12-15-21-28-54), Rutherford (11), Ballah (31), Charlton (33), Acres (48), McGilvray (64), and Todd and Wolbach (75) contributed to the Canadian literature on the subject.

From Minnesota the disease is mentioned by Brimhall, Wesbrook and Bracken (10) in 1903 and by Beebe (18) in 1905.

From Nebraska, the disease is described by Peters (26) in 1906; from North Dakota by Van Es (37,68) in 1907 and 1910; from Texas by Francis and Marsteller (42) in 1908; from Nevada by Mack (50-51-65-73) in 1909 and 1910; from Louisiana by Flower (57) in 1909; from Wyoming and Colorado by Whitehouse (56) in 1909; from Oklahoma, Kansas and Missouri by Kinsley (63-72) in 1910; from Washington by Thatcher (71) in 1910 and from the delta country of the Mississippi and Arkansas by Norton (82) in 1911.

General descriptions of the disease were published by Mohler (46-52-53-66) in 1908, 1909, and 1910.

Darling (58) writing from the Panama Canal Zone, also makes mention of the disease clinically corresponding to the swamp-fever of the United States.

While it is by no means certain that there is always described under the name of "swamp-fever" one and the same disease, there is sufficient evidence to show that we have among the horses of a large area of the continent, a disease, which has thus far only received purely local attention.

On the European continent also there seems to exist a disease, which is exceedingly similar to ours (at least for so far as that of the Red River Valley is concerned) and probably identical to it.

The disease has been described by various French writers since 1843. In more recent times something like our swamp-fever was observed in 1883 by Zschokke (1) in Switzerland; in 1886 by Fröhner (2) in southern Germany;

in 1890 by Ostertag (3) in Berlin; in 1901 by Köpke (8) in the vicinity of Metz; in 1904 by Jarmatz (14) among the farm horses of Lorraine and by Vallée and Carré (16) in various sections of France; in 1906 by Béghin (22) near Florennes in Belgium; in 1906 and 1908 by Ries (27-47) in Luxemburg; in 1907 by Brickman (32) in Sweden and by Charon (34) near Sainte Menehoulde; in 1907 by Ostertag (35) in the vicinity of Trier; in 1908 by Friedrich (44) in Kur-Hessen; and, in 1909 by Hutyra and Marek (69) in Hungary.

It is not quite certain that the American disease is identical to the one described, but there are very strong indications that it is.

The name under which the disease is most widely known in this country plainly indicates that it is most prevalent in low, marshy sections or during wet seasons. Torrance (3) states that the worst infected districts are notably those nearest to sea-level and during wet seasons the losses there are very great. In a later report (15) he points out that the ebb of the disease in Manitoba, which had a dry summer, appears to coincide with an increase in the Northwest territories, where the season was unusually wet, a fact which lends support to the theory of swamp-infection as the main source of the disease.

In the investigation of the disease in Minnesota by Brimhall, Wesbrook and Bracken (10), two distinct foci of distribution came under observation. In one focus, the same geologic formation generally prevails. The soil is a heavy black loam, while the country is markedly flat and there is but little natural drainage. Bogs and small lakes and ponds are very apt to form, wherever flowing wells are present. Wherever the land is a little lower than the surrounding country, water will stand on it for a considerable time each year or there may be an abundant growth of swamp-grass. The second focus of the disease did not show the same uniformity in geologic features and topography, nor was the disease as generally prevalent as was the case in the other focus. The country is rolling, with an exceptionally light sandy soil, in many places well wooded. In neither of the two districts could low places be excluded, although the observers failed to find conclusive evidence of the relation between those circumstances and the occurrence of swamp-fever.

Rutherford (11) states that the disease is most prevalent in a low lying swampy country. Peters (26) found the disease on marshy pastures during wet seasons. Francis and Marsteller (42) describe the disease as occuring in the flat coast region of their state. Acres (48) found the disease only on low-lying and swampy pastures where the water becomes stagnant during the hot months of the year. Mohler (52-66) finds that the disease is most prevalent in low-lying and badly drained sections of the country and considers the drainage of infected pastures indicated, as a preventative measure. According to him the disease has been found in altitudes as high as 7,500 feet on marshy pastures during wet seasons. Kinsley (63) observed that the wet seasons seemed to increase the prevalence of the disease, which, however, is as liable to be found on high land as on low.

In the description by European observers, the relations of the disease with low, marshy pastures is not emphasized, although Brickman (82) describes it as most frequent in wet regions. Ries (47) states the farms situated in wooded regions have especially been affected.

For so far as our own observations go, it would seem that most of our cases come from the lower sections of the country, although many reports indicate that the disease may occur on high and dry land, where deficient drainage could not possibly be an etiologic factor.

Most of the cases of swamp-fever occur during the months of summer and early fall. Torrance (9) finds that the cases usually make their appearance in the month of June and increase in frequency until September and October, while Brimhall, Wesbrook and Bracken (10) state that they were not prepared to make a definite statement in relation to the time of the year when infection takes place, but that it appeared that the cases seemed to begin in the early summer months and to increase in number during the months of July, and August. Rutherford (11) speaking of the disease in Canada, states that it is the most common in the late summer and early autumn, but that a few fresh cases come under observation between December and the latter part of July. In the outbreak described by Mack (50) the disease appeared during the summer of 1906. It abated during cold weather but only to reappear with equal fatality during the following summer, but a year hence there were but few sporadic cases. Mohler (52) found that the disease makes its appearance in June and increases in frequency until October. The observations of Kinsley (68) show that swamp-fever is most prevalent in the summer months, the initial attack usually occurring during July, August or September.

Among the European data on the disease, we find that the outbreak described by Köpke (8) also occurred during the latter part of the summer and autumn, while Ries (47) confirms an estivo-autumn recrudescence of the malady observed before.

The foregoing observations are fully in accord with the usual occurrence of swamp-fever as it is met with in North Dakota. The great majority of our cases show up for the first time during the months of August and September, and it is probable that cases which occur during the winter contracted the disease during the preceding summer or autumn.

It is difficult to undertake to place an estimate on the economic importance of the disease. While we cannot express losses in money values, there seems to be no question as to the serious nature the disease may assume. Rutherford (11) reports that in some of the Canadian districts the mortality is simply appalling and that settlers were ruined by the loss of their horses. Todd and Wolbach (75) writing about the Canadian disease state that one farmer lost fourteen horses in four years and that another near Winnipeg lost forty in the same length of time. A firm of contractors working on a railroad near Edmonton in 1908 had seventeen losses from swamp-fever in a herd of twenty-eight horses. They also quote a statement made by the animal insurance companies to the effect that seventy per cent of the death claims for horses made in Manitoba are on account of swamp-fever. In other parts of the country, the disease is entirely unknown, while in a few sections sporadic cases occur from time to time. In one of the Red River Valley counties of North Dakota, where the disease has been prevalent for 8 to 10 years, thirteen farms with a total horse population of 242 head sustained a loss of 98 head or about 40.5 per cent during the year 1908. On another farm in the same district, twenty-four horses succombed to the disease within four years and the loss forced the owner to close out his business. Numerous instances of this sort are recorded for the different "swamp-fever" districts, and fairly indicate the havoc of which the disease is capable. Those figures also point to the serious possibilities in case the disease should become more generally distributed. We should not pass by "swamp-fever" figures, however, without a word of caution against their acceptance at their face value.

It is probable that only those cases of the disease which go on to the chronic anemic stage are diagnosed as such and that the more acute forms of it are never properly identified. On the other hand, there is a strong tendency on the part of veterinarians and horse owners, to regard any chronic disease accompanied by anemia as swamp-fever, while in not a few instances anything more or less difficult in diagnosis or in which a diagnosis at the spur of the moment is impossible is being charged to the disease under consideration.

In the light of our present knowledge of the disease, swamp-fever may be defined as a specific septicemia of the horse species, due to the presence and vital activity of virus, which thus far has been demonstrated only in an ultramicroscopic form and characterized by a more or less intermittent fever and albuminuria, accompanied or not accompanied by a progressive anemia.

Various views have been advanced in regard to the etiology of "swamp-fever." Zschokke (1) writing about an anemic disease of horses, as seen in Switzerland, was led to think that the disease was caused by an agent similar to that of malaria. Fröhner (2) also points to the probability of some infection as an etiologic factor, and in support of such a possibility, he mentions the simultaneous sickening of several animals in one stable, the sudden febrile attacks in the beginning and the malaria-like exacerbations and remissions of the fever during the further course of the disease.

On the other hand Watson (6) expresses himself, that there is no doubt but that it is caused by a vegetable poison taken into the system through the mouth. Köpke (8) believes that the disease described by him is one of infection, although he was led to doubt, because it happened frequently that horses exposed to infection did not become sick at all.

In the first description by Torrance (9) he states that the question of contagion was not settled. He had kept fever cases in the most intimate contact with healthy horses without observing transmission of the disease, while his inoculation experiments had up to the time of writing proved negative. He also states that there appeared to be reasons to think, that paludism plays an etiologic part, basing this opinion upon the prevalence of the disease in low-lying districts. In another article, Torrance (12) expresses himself as certain that the disease is not identical with surra and mentions a large bacillus, non-motile, spore-forming and

Gram staining as having a possible connection with the disease. Later, the same author (21) "thought" that he saw several round bodies in the erythrocytes which occurred either singly or arranged in groups of four. Still later Torrance (28) reports that in his investigation a point was reached at which it seemd reasonable to exclude trypanosoma or plasmodia from the possible causes of the disease. In a publication of still later date, Torrance (54) reports a case in support of the view that a disease closely simulating swamp-fever in its clinical manifestations, may be accompanied or caused by the presence of large numbers of worms belonging to two closely allied species (Sclerostomum tetracanthum et armatum). The suggestion of a hemolytic agent, that may originate in the intestinal tract by bacterial activity is made by Torrance (21).

In the investigations in Minnesota by Brimhall, Wesbrook, and Bracken (10), the possibility of horses of the infected districts drinking from pools, marshes or lakes could not be excluded, while attention is called to the possible part played by insects or arachnoids as factors in "aiding saprophytic development of parasitic bacteria," as well as to the overworked condition of horses and their irregular food supply as influencing their resistance power to infection. The same investigators made very exhaustive bacteriologic studies with the material at their disposal and report that a small, non-motile, ovoid bacillus, which they named B. equisepticus, was present in practically all cases. It was further found that B. equisepticus was highly virulent to rabbits, pigeons, sparrows, while calves were less susceptible. Dogs and swine appeared to be resistant. Horses succumbed to the infection and "at autopsy, the findings were practically those met with in clinical cases of acute swamp-fever."

Other experiments were also carried on with an organism spoken of as B. pyrogenes equinus as well as with the toxines of both organisms mentioned. The authors mentioned, further state that an etiologic relationship between

B. equisepticus and the disease "swamp-fever" would therefore seem to be a safe deduction from the autopsy findings in clinical cases and the experimental inoculations.

Jarmatz (14) is of the opinion that the disease begins early in life, during the first months even and attributes it especially to the results of in-breeding, which is very much in vogue in the section of Lorraine, where he made his observations. Insufficient nutrition also shares in the production of the disease.

Bacteria were isolated from most cases by Beebe (18) but his experiments did not seem to establish a causative relationship of those micro-organisms to the disease. In the same report, the author mentions the case of a horse contracting the disease after having been driven with a probable case of "swamp-fever."

Peters (26) made cultures from spleen, blood, kidneys, and urine, but those cultures inoculated into smaller animals failed to infect. His autopsies showed a large number of worms "known as tetracanthum" and he seems to lean to the theory that intestinal parasites may be etiologic factors.

Ries (27) deems the theory that intestinal helminths exercise a preponderating influence to be quite supportable and calls attention to the fact that he once made the statement that he accused the larvæ of Gastrophilus to play a part in the propagation of pernicious anemia, either by being the carrier of infection, by opening up a port of entrance or by causing a general weakening of the resistance power. Ries thinks that the frequent occurrence of the disease on isolated farms situated in wooded regions supports his theory.

Ballah (31) injected some cavia with "swamp-fever" blood and the animals promptly became sick. It was proven, however, that those results could be attributed to a streptococcus, which occurred in the blood of a horse as a secondary infection. This author was induced by certain changes found in the liver to study this organ more closely for the presence of micro-organisms, and in the course of this investigation he found certain liver-cell inclusions, which he believed to the protozoa and probably the specific cause of the disease. Those bodies were found by Ballah in over 50 per cent of the cases examined, but they were absent in all specimens of normal liver from horses or other animals.

Charlton (33) injected several laboratory animals with material from swamp-fever cases. After two weeks, some of the cats showed a slight rise in temperature and appeared somewhat ill. The fever was irregular and although the animals ate well, they failed to thrive and had an unhealthy appearance. One of the cats developed a well defined edema all along the belly about five weeks after injection. The edema lasted about two months, when it disappeared, the animal afterward remaining in good health. Two of the smaller cats died about three months after injection, but horses injected with the blood of the sick cats remained in good health. Specific organisms were not found.

Brickman (32) in cases, in many respects similar to the pernicious form of anemia in France, claims to have found parasites resembling those of malaria in the blood corpuscles.

Van Es (37) was able to isolate several bacterial species from the blood of "swamp-fever" cases and his observations on the damage done by certain helminths may be an indication as to how the micro-organisms found their way into the general circulation. There was no evidence adduced, however, that the conditions found bore an etiologic relation to the disease under investigation.

Hundreds of blood examinations were made by Francis and Marsteller (42) but none of them revealed the presence of blood parasites. Cultures from the blood on various media also led to negative results. In a later report the same authors (81) described an experiment on the possibility of transmission of infectious anemia through the agency of

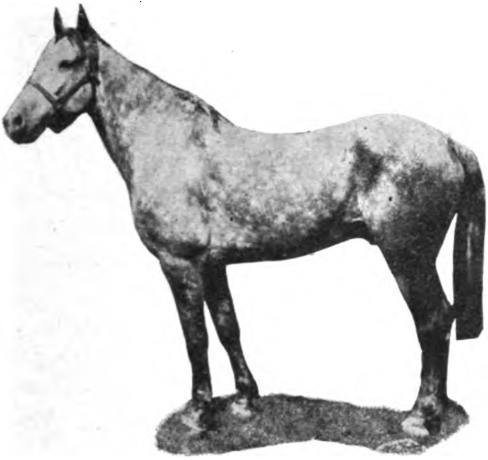


Fig. 1. A field case, No. 921, about one month before death.

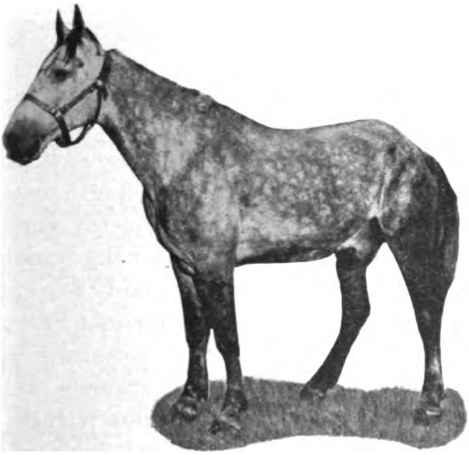


Fig. 2. The same horse as shown in Fig. 1 about one week before death. Note the marked edematous swellings of brisket, lower part of chest and abdomen, the sheath and the right hind leg.

Böophilus annulatus, but in the one case tried the results were negative.

Mack (50) isolated various bacteria but their relationship to the disease under consideration was not positively demonstrated, neither did he find evidence of direct contagion.

The invariable presence of parasitic aneurism in all the cases subjected to autopsy by Whitehouse (56) led him to look with considerable suspicion upon this fact.

Trypanosoma were found by Darling (58) in the blood of an American gelding and a number of mules in the Panama Canal Zone. These animals were suffering from a disease which corresponds clinically with the descriptions of "swamp-fever" published in this country. The readiness with which Darling infected a great assortment of various animal species with his trypanosoma renders the identity of the Panama disease with our swamp-fever rather questionable, however. His inoculations with filtered blood did not permit of definite conclusions and hence the reports of further experiments by this investigator will be looked forward to with considerable interest.

Kinsley (63) reports the instance of a farm, which has been infected for twelve or fourteen years and on which horses were lost with the disease every year, while on a neighboring farm not more than sixty rods away, there never was a case. On another farm five horses were lost during the winter and a pony placed in the same stable for three or four weeks during the following summer became affected and died. On the other hand, several instances were observed in which one of the horses of a certain team had become infected and the other remained normal, and this, in spite of the fact, that the animals were watered from the same pail, and fed in the same trough. Colts appear to suck from infected mares with impunity, while in other instances sucking colts become affected, although the mares remain healthy. Horses and mules seem equally susceptible, while the age of the animals seems to have no more influence on susceptibility than the breeds to which the animals belong.

It is probable that Torrance (12) was the first to actually transmit the disease by direct infection, although from his report it does not appear that he clearly recognized the fact. In 1902 this investigator observed a rise of temperature in a horse injected with swamp-fever blood on the 12th day after injection and he merely holds it for probable that the animal had become infected. This horse had two more subsequent rises of temperature at intervals of 10 to 12 days, but without any clinical symptoms of the disease.

The first serious attempt to clear up the etiology of the disease was made by Vallée and Carré (16-17-19-23-36) and they succeeded in doing so to a remarkable extent, at least, for so far as the European disease was concerned. While the infectious nature of the disease had been suspected for some time, they definitely settled the question of transmitting the disease to a healthy animal by the injection of blood from a diseased one. In their first communication Vallée and Carré (16) relate that in their first experimental subject, the disease ran its course, identical to the natural disease in 57 days and how the blood count dropped from the normal 7,800,000 to 2,800,000 on the day of death. The autopsy revealed the ordinary lesions of anemia, namely extreme muscular emaciation, subcutaneous, sub-serous, and peri-ganglionic edema, enlargement of the spleen, liver cirrhosis and hemorrhages of the bone-marrow. Bacteriologic research was not rewarded with positive results and a search for piroplasma or trypanosoma also failed to disclose those parasites. On the supposition that the etiologic factor of the disease might belong to the invisible viruses, Vallée and Carré made a mixture of 500 c. c. of blood serum coming from a sick animal with 200 c. c. of physiologic salt solution and added to it a culture of an extremely virulent ovine pasteurella. This mixture was passed through a special filter bougie and the opalescent liquid passing through the filter was injected in doses of 20 c. c. into the veins of some rabbits and into the peritoneum of cavia, which animals remained healthy. This experiment showed the efficiency of the filter. Next the investigators injected 500 c. c. of the filtered liquid into a healthy horse and found that after a lapse of a certain period of incubation the animal presented symptoms of an absolutely typic anemia. It was thus fairly well established that the etiologic factor in the disease is a so-called ultra-microscopic organism.

Somewhat later Vallée and Carré (17) completed their previous report and state that it is easy to maintain the virus by successive passages through the horse, the virulence increasing. They also found that the anemia in reality only constitutes one of the forms of an infectious disease, which often reveals itself under an entirely different aspect. In fact, three types of the disease may be recognized and Vallée and Carré emphasize that those three types unquestionably belong to one and the same affection as they are experimentally reversible. They also infected the ass and showed that virulent blood loses nothing of its virulence by being diluted five times and by being filtered either through a Berkefeld filter or through Chamberland bougies F or B. In the same series of experiments, Vallée and Carré also proved that the disease is transmissible by the digestive tract, as a horse fed on 20 c. c. of virulent blood promptly contracted the disease. Note is also made of the fact that horses which were apparently absolutely cured of the chronic form of the disease still retained their full infective powers and hence Vallée and Carré express the opinion that the presence of such virus-carriers constitutes in infected regions a great obstacle to the extermination of the disease by prophylactic measures.

Carré and Vallée (19) in a later report cite an instance which tends to show the infectiveness of the urine of an apparently recovered case. Continuing their studies Carré and Vallée (28) found that the quantity of virulent blood injected into a healthy experimental animal had no influence upon the course of the disease.

Cattle, sheep, goats, dogs, rabbits, cavias, mice and white rats proved to be refractive to infection.

Carré and Vallée report that the virus is destroyed by heating to 58° C. for one hour, but that drying in vacuum at room temperature does not alter its virulence. The dried material from 1 c. c. of virulent blood kept for ten days and then inoculated into a vigorous horse, kills the same in thirty days, but after storing this substance for seven months, it is no longer disease producing.

The authors metioned, further report that the keeping of virus outside of the body seems to rob it gradually of its virulence, but that putrefaction did not seem to disturb the vitality of the virus.

Carré and Vallée are of the opinion that the natural mode of transmission of the disease takes place by food stuffs and drinking water soiled by virulent urine and probably also the fæces, but they did not succeed in establishing any relationship between blood sucking animals and the distribution of the disease.

The results of the experiments of Vallée and Carré relating to the ultra-microscopic nature of the virus have since been confirmed by various investigators, Charon (84), Ostertag (35), Francis and Marsteller (42-81), Hempel (49), Mack (50), Mohler (52-66), Van Es (68); Todd and Wolbach (75) transmitted the disease by intra-peritoneal injection.

In the experiments of Ostertag (35), attempts to transmit the disease by means of the saliva failed, but he succeeded to bring about infection with 20 c. c. of blood serum of an acute case, after it had been kept on ice for seven weeks.

Hempel (49) reports that virulent material which was stored on ice for some time and given by the mouth in small quantities was not capable of producing the slightest reaction, although it produced, a typical infection when given subcutaneously in one-fourth of the dose used in the feeding experiments. Material from a case in the dormant stage of the disease, when given intravenously in doses of

120 c. c. produced a slight form of the disease and when given per os in a dose $2\frac{1}{2}$ times as great, a one day fever period was observed after 21 days incubation. Given intravenously or subcutaneously, small amounts of virulent blood will produce infection, but larger quantities are required if infection per os is to be produced.

The question of a transmission of the disease by contagion has not received much attention, but the few data on record seem to indicate that this means of transmission is not an easy one.

Melvin (70) reports the experimental exposure of a healthy horse, which was quartered in a stall adjacent to one containing a sick horse for seven months and which failed to transmit the disease.

Francis and Marsteller (81) kept a susceptible pony continually exposed to swamp-fever infection for more than two years by intimately associating it with infected animals in a small pasture, without the experimental pony becoming infected.

In our own experiments with the disease as it occurs in the Red River Valley, the results obtained by Vallée and Carré were practically repeated.

During the latter part of 1907, we injected an apparently healthy horse intravenously with 8 c. c. of blood from a typical chronic field case and the injection was followed some eight days later by the initial fever attack, which we have since learned to recognize as evidence of positive infection. Since that time, we have succeeded in transmitting the disease by means of filtered (sterile as far as cultures are concerned) diluted serum.

In our hands, not only the disease was transmitted by subcutaneous or intravenous injections or virulent blood, but we also produced infection by giving capsules filled with virulent blood by the mouth. In addition, we found that urine either injected subcutaneously or given by the mouth is capable of transmitting the virus.

For so far as our investigations go, it does not appear that the virus is eliminated by the bowels. The subcutaneous injection of 100 c. c. of an extract of fæces from a virulent horse into a susceptible horse was not followed by any reaction. In another case four liters of a similar extract in which 1790 G. of fæces from a virulent case were used and which were introduced into the stomach by means of a stomach tube failed to bring forth any noticeable results.

The latter experiment was repeated with larger quantities of extract made with fæces from another case, using a different experimental horse, with the same results. The susceptibility of the experimental horses used was proven by their subsequent infection when injected with virulent blood.

From the various experiments quoted, it seems safe to conclude that the disease is due to an ultra-microscopic virus and that this is the primary factor to be considered in the problem. The experiments have eliminated poisonous plants as a factor, and the readiness by which a virus can be caused to make several passages in unbroken succession also sets aside the etiologic importance of intoxication by intestinal helminths. There can be no question as to the possibility of intestinal worms in producing outbreaks of anemic disease, and in the study of such diseases, their presence should not be neglected, but in the disease under consideration, they cannot be regarded as primary factors.

The importance of certain helminths as producers of anemia and as instruments of opening the way for bacterial invasion is strongly pointed out by the publications of Glage (24) and of Weinberg (38-39).

For the time being, the demonstration of ultra-microscopic virus must not be accepted as final, and the search for blood micro-parasites should not be discontinued. We may readily conceive the possibility that in the metamorphosis of a micro-parasite there may occur a stage, during which the forms become filter passers.

The nature of the virus was not further investigated by the writers, with the exception of its behavior toward freezing temperatures.

The following observations were made:

A quantity of virulent blood was exposed to freezing for 24 hours during which the minimum temperatures recorded was 10° F. The blood was permitted to thaw at room temperature and 240 c. c. were injected subcutaneously into an experimental horse with the result that the animal sickened on the ninth day and died on the fifteenth day after injection.

Another quantity of blood was exposed to freezing, the prevailing temperatures being indicated by the following table:

Date	Maximum Temp. F.	Minimum Temp. F.	Date	Maximum Temp. F.	Minimum Temp. F.
Jan. 3	-10	-26	Jan. 20	17	0
Jan. 4	16	-22	Jan. 21	14	-15
Jan. 5	0	-14	Jan. 22	3	-13
Jan. 6	3	- 7	Jan. 23	2	-12
Jan. 7	15	-14	Jan. 24	24	0
Jan. 8	15	-13	Jan. 25	28	- 1
Jan. 9	9	- 9	Jan. 26	27	11
Jan. 10	31	-14	Jan. 27	11	3
Jan. 11	-15	-23	Jan. 28	5	13
Jan. 12	0	-23	Jan. 29	33	3
Jan. 13	0	-22	Jan. 30	16	-13
Jan. 14	-11	-22	Jan. 31	23	- 9
Jan. 15	- 2	-19	Feb. 1	24	7
Jan. 16	- 3	-20	Feb. 2	23	-16
Jan. 17	8	-10	Feb. 3	10	-16
Jan. 18	8	- 7	Feb. 4	11	-14
Jan. 19	22	0			

On the fifteenth day of exposure, a quantity of this blood was thawed and 240 c. c. of it injected into an experimental horse. This horse developed fever after an incubation period of forty-nine days and died eight days later.

A similar quantity of this blood was injected into another experimental case after it had been exposed for thirty days with the result that the animal developed fever on the 45th day, dying 6 days later.

From the above observation it would seem that if severe freezing has any effect at all on the virulence of the blood, it merely consists of lengthening the incubation period. Before concluding definitely on this point, however, further research will be required, especially in view of the unusually long period of incubation.

In certain cases of pernicious anemia of man, the presence of peculiar bodies were found by Perles (5). *He proposes the name of anemia-bodies for them and describes them as elongated, elliptical, very thin and narrow, flexible, colorless, and highly refractive leaflets. Perles failed to either stain or cultivate them, nor could he find them in cases of secondary anemia. Hoefer* (62) *apparently found certain protozoa in a case of severe anemia eight days after the beginning of sickness, but the question whether or not they constituted an etiologic factor could not be decided.*

The transmission of "swamp-fever" to other animals seems to be denied by most authors. Carré and Vallée (28) tried to infect other animals, but without positive results. Ostertag (35) reports that in the district where he studied the disease, a transmission to other domestic animals had never been observed and attempts to transmit the disease artifically also resulted negatively. Man had not been known to contract the disease, although many persons constantly cared for infected horses and even consumed their meat. Francis and Marsteller (42) failed to obtain positive evidence of infection after injecting cattle, sheep, goats, pigs and dogs with virulent blood. Charlton (33) observed that injection with virulent "swamp-fever" blood into cats was followed by illness, but the blood of the cats so affected proved to be innocuous to horses. Mack (73) in his latest publication states that in the Nevada disease there is no evidence that it is contagious and that while there is every clinical indication, that it is a specific infectious disease, he must have more conclusive evidence than his experiments have yet afforded before one is warranted in pronouncing it such. At the time, however, he would venture no opinion as to the identity or non-identity of the Nevada disease with the affections reported from other sections. Todd and Wolbach (75) injected with swamp-fever virus four cavias, two mice, nine rats, two rabbits, ten dogs, two kittens and one sheep and no symptoms which could be attributed to swamp-fever followed in any of the animals experimented with.

In our own work, a similar condition was experienced. A number of cavias were injected with virulent blood and several among them showed a rise of temperature after a few days, while still later some of the animals died. The blood of the sick pigs injected into a healthy horse, however, absolutely failed to cause any reaction.

The occurrence of anemic diseases among live stock other than the horse is generally well known, but as far as we know, nothing like swamp-fever has ever been observed, unless the case reported by Trincas (29) in the dog pertains to a similar disease. In this case the author demonstrated that anemia in the dog may be due to an ultra-microscopic virus.

The anatomic changes met with in swamp-fever are rarely of a striking character. They include degenerative changes in the various parenchyma, petechiæ, ecchymoses, especially about the serous membranes and endocardium, edematous conditions, certain changes in the lymphnodes and the bone marrow. The changes noted indicate a more general intoxication or septicemia than that the disease stamps a peculiar feature upon a certain organ or sets of organs. In the interpretation of the various lesions found,

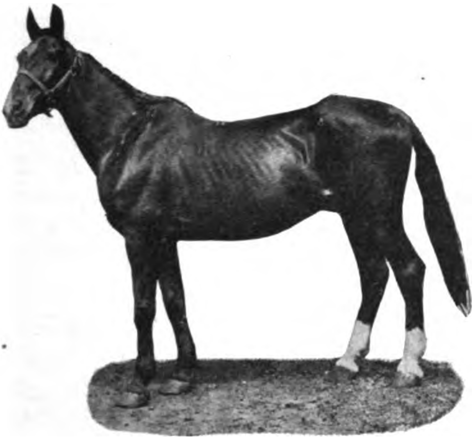


Fig. 3. A non-anemic field case No. 1032.

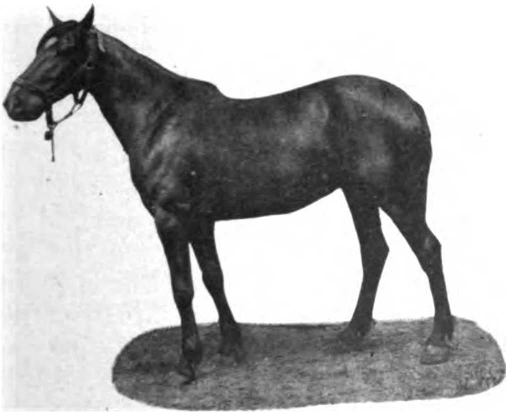


Fig. 4. Experimental horse No. 636, 33 months after original infection.

it should be borne in mind that in all probability secondary infections and influences also bear a large share in their production and that it is not always possible to determine which lesions to charge to the specific agent of "swamp-fever" and which are to be credited to other determining factors. For the purpose of presenting the pathologic anatomy of swamp-fever as fully as the importance of the subject demands, it seems wise to quote from the descriptions of various observers in addition to mentioning our own findings.

Taylor (7) found the blood of the carcass darker and more fluid that normal. Numerous petechiæ and hemorrhagic spots were visible in the fasciæ of dorsal and lumbar muscles. Both heart cavities were thickly spotted with black hemorrhagic areas. The intestinal surfaces were also studded with petechiæ. The mesenteric lymphnodes were black as if filled with dark blood. The spleen was considerably enlarged. The kidneys showed nephritis (interstitial). The muscles showed hemorrhages both in the perimysium and between the fibres themselves. Taylor states that numerous black bodies scattered throughout the lungs are "the most striking features."

In the experience of Köpke (8) the carcasses dead with the disease were highly emaciated, hide-bound, and presented a dull, rough coat. The mucosæ were perfectly anemic and the eye-balls were sunk deeply into the orbits. The subcutaneous veins appeared almost bloodless and the subcutis of the thorax, belly, prepuce, and the hind legs were markedly edematous. The musculature, which immediately after exposure, had a pale red color, assumed a characteristic reddish yellow, almost orange red tint after an exposure to the air for a few hours. The mesocolon showed numerous hemorrhages of the size of a pea to that of a hazelnut. The mesenteric lymphnodes were two or three times their normal size on account of the edematous swelling. The mucosa of the intestines showed petechiæ in two of the cases. In the third case, the mucosa was thickened, this thickening being firm, and more of a fibrous connective tissue nature than edematous. Liver and spleen were normal in size, the former showing a slight parenchymatous cloudiness. The markedly enlarged kidneys appeared pale red and were so friable that their entirety could scarcely be preserved, when they were taken out of their capsule. Their parenchyma was cloudy. The heart was always considerably enlarged and the myocardium degenerated to a high degree so that it presented a pale-grey-red color and a parboiled appearance. In the ventricles, especially about the columnæ carnæ, extensive endocardial hemorrhages could be demonstrated.

Torrance (9) describes anemaciated state of the carcass with a most remarkable absence of adipose. The tissues were blanched. The blood is often firmly clotted in all the vessels, the clot having the appearance of yellow jelly. The abdominal viscera are normal in color but frequently studded with petechiæ on the serous surface. The spleen is generally much enlarged, reaching in some cases a weight of six pounds, while its surface appearance is normal. The liver is not much changed in appearance, but is sometimes studded with flakes of lymph. The kidneys, not infrequently, show evidence of chronic nephritis. A few petechiæ may be noted on the surface of the lungs. The heart is generally enlarged, sometimes much hypertrophied, reaching in one case a weight of twelve pounds and fourteen ounces. The pericardium is frequently studded with petechiæ and the pericardial fluid in some cases is greatly increased. Spinal cord and brain are found to be in a normal condition.

Brimhall, Wesbrook, and Bracken (10) report sharply defined edemata in the regions of the chest, the abdomen and the limbs. In some cases there was evidence to show that such subcutaneous edematous areas became purulent later on. Conditions of this kind were met with between the pectoral muscles and those of the legs. They were also seen in the mediastinum and in the auriculo-ventricular groove in advanced cases. The deeper layers of the skin and the subcutaneous connective tissue showed in nearly all cases hemorrhages, varying in size from petechiæ to irregular spots, two or three inches in diameter. Such hemorrhages were also found between and in muscles, fasciæ, synoviæ, lymphnodes, serous membranes and the heart. The lungs were sometimes stippled with red spots, showing through the pleura, while at other times irregular areas of hemorrhage occurred which completely filled several contiguous lobules. The spleen as a rule was found to be spotted with irregular red blotches and in certain instances well marked and extensive infarcts were to be seen. In a few instances the organ seemed almost entirely devoid of hemorrhages. The changes shown by the kidneys varied and included petechiæ, large hemorrhages under the capsule and parenchymatous nephritis. Hemorrhagic areas were quite frequently seen in the mesenteries and the walls of the stomach and intestines. In some cases they were several inches in diameter. Often they were sub-peritoneal, but in a number of instances they involved the entire intestinal wall. While the authors found it impossible to ascertain accurately at what stage of the disease hemorrhages are most likely to occur, it would appear that they were more common in advanced cases, when the blood changes were most marked. Abscesses were frequent in the Minnesota cases and the inflammation of the serous surfaces was so common as to be recorded as characteristic of the disease. The heart was enlarged, in many cases showing numerous hemorrhagic patches underneath the endocardium or epicardium and occasionally involving the whole thickness of the heart wall. Frequently there was an increase in the pericardial fluid and very occasionally a sero-fibrinous pericarditis was present. In some instances, white depressed areas, irregular in shape and size probably indicated the seat of old hemorrhages and infarcts. Histologic examination showed that in those areas the heart muscle fibers are replaced by connective tissue. The lymphnodes are frequently swollen and infiltrated with a gelatinous exudate. In all cases lymphnodes could be found in which marked hemorrhages could be demonstrated and the whole structure was often found to be hemorrhagically infiltrated. The liver usually was increased in size and congested and when peritonitis was marked flakes of lymph covered its surface. The liver tissue was frequently softened, light in color, giving evidence of parenchymatous changes. Branches of the portal vein were quite frequently found to contain whitish thrombi. Cirrhosis was met with twice. The bladder often showed hemorrhages in its wall, sometimes involving the whole thickness and the areas being some inches in diameter.

In the cases studied by Carré and Vallée (28), the lesions varied according to the evolution of the disease and were especially associated with the blood, the heart, the spleen, the lymphnodes, and the bone-marrow. In addition there were changes in the kidneys, liver, intestines and edemata of various parts. The lymphnodes in acute and sub-acute cases and also in the chronic cases during an acute exacerbation will show congestion, even hemorrhages, especially those of the mesentery and the spleen. In the cases dead with exhaustion, the nodes will show a simple edematous enlargement, while at the same time they are surrounded by a yellow edematous mass. The spleen is nearly always enlarged, doubled or tripled in volume. There is no softening, on the contrary there is thickening, the organ being lumpy in the middle and seems to have gained in consistency. On section the pulp is paler than usual and the splenic bodies are hypertrophic, granular and grayish. In acute cases, the capsule is speckled by ecchymoses. The bone-marrow most generally presents extremely marked alterations in all the patients. The lesions are particularly intense in the femurs of which the marrow is transformed for a great part of its height in a veritable bloody, brick-red or blackish mush and in consistency resembles foetal marrow. The histologic examination reveals the special characters of the latter, like it does in all the known anemic conditions. Changes of the heart are exceedingly common. In the acute type it is speckled over by multiple ecchymoses, sub-pericardial and sub-endocardial. The myocardium is marked by numerous hemorrhagic foci, triangular in shape and of several square centimeters in area. One may observe a valvular endocarditis, this being best described by comparing theirs to the aspect of an eschar due to a weak caustic. In the chronic cases the myocardium is discolored, marked by the remains of hemorrhages, pink or greyish in color and one sees occasionally a slight valvular edema and atheromatous lesions of the aorta. The liver is generally enlarged, of a washed yellow color, sometimes stippled with fine white specks or it presents the typic aspect of the liver of cardiac insufficiency. The liver tissue is more friable and can be readily torn. The kidneys are pale, discolored in the chronic types, hemorrhagic in the acute forms. The capsule can be readily stripped. Sometimes we meet with well rounded pin-head abscesses in the cortical portion and which project under the capsule of the organ. The intestines are normal in the chronic cases, but in the acute ones on the contrary they are speckled with multiple sub-serous hemorrhages. The mucosa is the seat of a more or less intense congestion, while the muscular coat may present the same features. The lesions are generally quite extensive in the large intestines, which are sometimes entirely hemorrhagic but in the small intestines the lesions are more discreet. The lungs were always normal with the exception of a few sub-serous petechiæ.

Charon (34) notes the following changes seen during the autopsy of a natural case; emaciation, absence of a subcutaneous edema, the presence of three or four liters of a lemon-colored serous fluid in the peritoneum. The lymphnodes, the superficial ones, as well as those of the viscera, are enlarged, infiltrated, juicy, showing on the cut surface numerous hemorrhagic foci. There was an absence of internal fat, the liver in normal color, but with its capsule thickened. The spleen is nearly three times its normal size and weighs 2100 grammes. The kidneys have a sclerous aspect from periphery to center. The cortical portion is discolored, the medulla is pale. A section of the bones reveals the marrow to be altered in its entirity, foetal and hemorrhagic. The endocardium is a little thickened. The same author also gives an account of the autopsy of an experimental case. He states that the cadaver is poor. There is no subcutaneous edema. The muscles have a normal color and there is no exudate in the body cavities. The lymphnodes of the groin, spleen, kidneys are very much enlarged and those of the spleen show numerous small hemorrhagic foci. There is a wasting of the internal fat. The liver has a normal color and Glisson's capsule is thickened. The spleen is triple the normal size, weighing 2600 grammes. The kidneys are slightly discolored. A section of the femur shows a hemorrhagic focus 10 c. m. in width and 1 c. m. in thickness. There is foetal marrow of the consistency of vaseline. The heart presents a hemorrhagic area of the right ventricle extending for 2 m. m. into the myocardium.

The autopsies made by Francis and Marsteller (42) revealed extreme emaciation, some edematous swellings along the lower part of the body and usually some bed sores. The muscles were pale and the blood watery. Petechiæ were noted on the heart and pericardium, while some enlargement of the heart was observed. There was a marked enlargement of the spleen, the organ ranging in weight from four to eight pounds. The digestive apparatus was normal, while kidneys and liver showed no conspicuous changes. Aside from the lesions found in the blood, heart and spleen, the authors were at a loss to account for the death of the animals.

Hutyra and Marek (69) state that the anatomic changes are those of an acute or chronic septicemia and are quite variable according to the duration of the disease. The spleen of horses, which died during an attack of the disease or during an acute exacerbation is considerable enlarged. Its capsule is tense, marked by hemorrhages, while the pulp is black red, projecting from the cut curface, mushy or even liquified. Sometimes there are found in the otherwise normal spleen, several large projecting, uneven areas, corresponding to very dark red softened foci. The slower the course of the disease, the slighter the changes in the spleen. In very protracted cases, the enlargement is often completely absent. For so far as the corresponding organs show hemorrhagic changes, the lymphnodes of the body show acute enlargement and a hemorrhagic condition. In chronic cases, the lymphnodes may not be altered or be at the most somewhat edematous. Sub-serous hemorrhages are a common finding but in the chronic cases they become inconspicuous. They are especially seen in connection with the cæcum and the colon, but in a less marked condition also in other parts of the peritoneum. Ecchymoses are always seen under ths capsule of the liver which is more or less, in some cases, even considerably, enlarged. The intestinal mucosa shows either isolated, round hemorrhages or there is a diffuse hemorrhagic condition with a bloody consistency of the intestinal contents. The heart with the exception of that in the very chronic cases, reveals sub-peri, sub-endo, or intramyocardial hemorrhages. The kidneys show hemorrhagic areas only in the acute cases and the same is seen in the lungs. Parenchymatous degeneration of kidneys, myocardium, and liver is always present. Hemorrhagic areas in the urinary bladder are not rare. The bone-marrow shows conspicuous and constant changes. Especially in the femur and the humerus, the yellow marrow is partly or entirely changed into a dark brown red or black red mass. In the cases of a more chronic course, only several circumscribed hemorrhages in the fatty marrow are shown. The latter may appear to be normal, while in chronic and acute cases, the red marrow in the extremities is apt to show a red discoloration. The same is seen in the marrow of the vertebræ, ribs, etc.

The most frequent lesions met by Mack (50) are hemorrhagic areas in various organs, but most constant in connection with the intestinal canal. In some instances various lymphnodes were found to be edematous and hyperæmic, in others they were normal. The bone-marrow was found to be altered. Especially that of the humerus and femur showed a color darker than normal, with red areas in various parts. Histologically various changes were encountered, but nothing of a striking, characteristic nature. The presence of the petechiæ and ecchymoses in many of the viscera was a notable feature of one of the autopsies, but those changes were absent in the other. The lymphnodes were either normal or hyperæmic or edematous. Parenchymatous degeneration was present in the kidneys and liver.

Mohler (66) reports that animals dead with the disease are very emaciated and anemic. There is a marked absence of adipose. Subcutaneous and intermuscular edema and hemorrhages are frequently observed, although the absence of gross lesions is remarkable in many cases. Mohler regards the petechiæ of the heart as the most predominating and most constant lesion. The organ is usually enlarged. In some cases the lungs may be studded with petechiæ, while a serous exudate may be present in the thorax. The pericardial fluid is also generally increased. Peritonitis and a hemorrhagic condition of the intestine may be encountered. The liver is generally normal, although sometimes it presents a few areas of degeneration. The spleen, at times, is found to be enlarged and covered by petechiæ. The kidneys may appear normal or anemic and flaccid, while under the microscope they usually show a chronic parenchymatous degeneration. The lymphnodes may be enlarged and hemorrhagic.

Melvin (70) expresses the opinion that in a broad general way, it may be said that the blood is the real seat of the trouble, and that any pathologic changes observed in the circulatory system or in the viscera are dependent on this rather than that the lesions in the circulatory system are primary. This author further states that the atrophy and weakening of the muscles of the hind quarters, causing

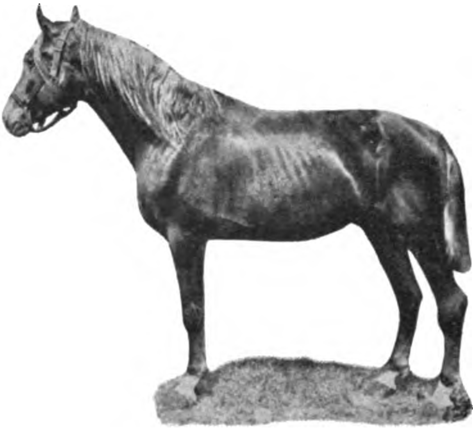


Fig. 5. Experimental horse No. 637, 25 months after original infection.

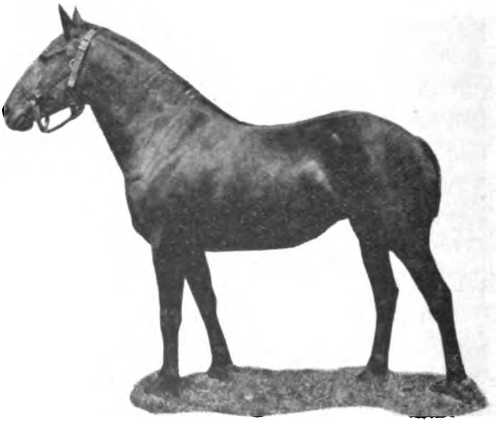


Fig. 6. Experimental horse No. 638, 23 months after original infection.

the consequent staggering gait undoubtedly are the result of metabolic disturbances, which are inherent in the blood rather than in the muscles themselves.

Todd and Wolbach (75) found in one case that the marrow of the long bones was fatty and that it did not contain blood forming cells.

In order to permit a comparison between the autopsy findings of the observers mentioned and those made at the North Dakota Experiment Station, we hereby submit some notes referring to the latter. Those notes only refer to such field cases of which the infectiousness was proven by the fact that their blood conferred the disease to normal horses and to the findings in connection with those experimental cases.

No. 562. (Field case taken from an outbreak near Harwood, N. D.) At the time of death this animal was greatly emaciated and after the removal of the skin the lack of adipose and the pallor of the muscle tissues were much in evidence. There was a slight yellow tinge noticeable, in connection with the subcutaneous connective tissues. The peritoneum showed evidence of a chronic inflammatory process by the numerous fine threads of fibrinous exudate and slight adhesions. Those lesions are found on the parietal as well as on the visceral portion, but perhaps more marked in connection with the latter although at this time it is not thought that there exists any connection between those peritoneal lesions and "swamp-fever." They are probably the result of parasitic migrations.

The spleen is considerably enlarged (weight 5 lbs. 12 oz.). Its peritoneal covering is thickened over its entire surface, which is covered with an organized fibrinous exudate. The splenic lymphnodes are enlarged. The spleen substance is of a little more solid consistency than is found under normal conditions, but does not otherwise present any marked features. Microscopically the spleen structures do not present noticeable changes. The liver, aside from being somewhat resistant to the knife, in its macroscopic aspect does not differ from the normal. Microtome sections of this organ reveal an apparently recent leucocyte infiltration of the interstitium. In several lobules, however, the round cells can also be seen between the cells of the parenchyma and around the vena centralis. Pigment deposits are common through the sections. The portal lymph-nodes are hemorrhagically infiltrated and exceedingly friable. They contain considerable deposits of a brownish yellow pigment. The intestines show no marked changes. The cæcum contains a number of nematodes. A verminous aneurism is present on the anterior mesenteric artery. The aneurism is quite large and extensive and shows evidence of a chronic existence. It contains a few embryos of Sclerostomum. The kidneys are of normal size but pale upon section. The histologic examination of those organs shows in many instances a beginning of the thickening of Bowman's capsule, the glomerulus frequently occupying all the available space. The structure of the glomerulus is generally intact but here and there degenerative changes have taken place and between the debris leucocytes may be seen. The epithelium of the tubules is fairly intact, whereever it is not encroached upon by interstitial changes. Interstitial round cell infiltration is confined to certain limited areas. It is limited in extent and at no place is any evidence of induration noticed. The arterial walls are somewhat thickened. The lungs are normal in appearance with the exception of a pneumonia focus of about 15 c. m. diameter situated in the anterior portion of the right lung. The solidification seems to follow the larger bronchioles and presents numerous hemorrhagic infiltrations. The histologic picture is that of a broncho-pneumonia, which here and there shows evidence of indurative changes. In most of the sections the alveolar walls can scarcely be recognized, owing to the dense masses of leucocytes. They also fill the bronchioles, which in many places seem to have become atrophic or obliterated. In many of the vessels thrombi are present, while near the periphery of the inflamed area hemorrhagic extravasation also fills the pulmonary alveoli. Unfortunate circumstances prevented the examination of the heart of this case.

No. 640. (Field case obtained from the neighborhood of Christine, N. D.) The cavader is very thin, the muscles are of normal color. The heart is normal in appearance but microscopically shows very slight evidence of granular degeneration and interstitial myocarditis which changes appear to be in their incipiency. The lungs are well contracted, presenting a few parasitic nodules under the pleura. There are also a few dark areas under the same membrane apparently due to a localized hyperemia giving rise to a somewhat mottled appearance of the regions involved. Several of the lymphnodes along the colon are enlarged and hyperemic. The intestines themselves are normal in appearance and contain a few specimens of Sclerostomum equinum. The liver is somewhat enlarged, dark in color and has its surface covered by fibrinous threads. Sections of this organ show parenchymatous degeneration, and interstitial hepatitis. Many lobules are infiltrated more or less with leucocytes and in some instances those cells are grouped in the form of small, round, narrowly circumscribed areas. There is a moderate degree of siderosis. The spleen is enlarged and shows numerous petechiæ on its surface. Microscopically, the trabeculæ seem thickened, while a considerable amount of pigment is in evidence. The kidneys are normal in appearance, and under the microscope, their parenchyma is fairly intact and interstitial round cell infiltration, although present, is insignificant in extent. The vessel walls are slightly thickened.

No. 635. (An experimental case infected by an injection of blood from No. 640.) The cavader is emaciated and there is a great reduction of adipose. The skeletal muscles have a normal color. There is a general peritonitis with a fibrinous exudate. The colon and cæcum are hyperemic. The mucosa of the colon is intensely inflamed or hemorrhagically infiltrated and a large quantity of hemorrhagic exudate is found in the lumen of the gut. Sections of the wall show it to be densely packed with leucocytes and blood debris, while numerous small necrotic areas are noted in the sub-mucosa. The floating colon is stippled with petechiæ. The omentum is densely inflamed. A small parasitic aneurism is noted in the anterior mesenteric artery and contains a few worm embryos. The liver is enlarged, hyperemic, very friable and histologically presents evidence of a considerable amount of fresh interstitial leucocyte infiltration. Many round cells are seen within the lobules. There is a moderate degree of siderosis. The spleen is about six times its normal size, its pulp very dark and soft. Sections of the organ show blood engorgement and a great amount of siderosis. The trabeculæ are not changed. The lungs are poorly contracted with a slight fibrinous exudate on the pleura and the heart is soft, flabby, par-boiled in appearance, but has its microscopic structures fairly well preserved. The kidneys are soft, friable and richly interspersed with miliary abscesses. A purulent pyelitis is in evidence. Microscopically, there is a considerable amount of interstitial nephritis, with here and there areas of dense acute inflammation (miliary abscesses). Bowman's capsule is considerably thickened. The epithelium is generally intact when not encroached upon by extratubular changes. The tubules themselves contain a small amount of granular debris, but there is no evidence of tube casts.

No. 744. (An experimental case infected by means of the blood of experimental case No. 636.) The well developed adipose presents a yellow tinge. The abdominal cavity contains about one-half liter of fluid. The peritoneum is bluish white in color, smooth, shiny and transparent. In the liver the lobules present a more than usual distinct demarcation, its capsule is tense and its borders rounded and of a light blue color. The spleen is apparently normal. The capsule of the kidney is tense and the tissue friable. Stomach and intestines as well as their contents present nothing abnormal. The left lung is pink in

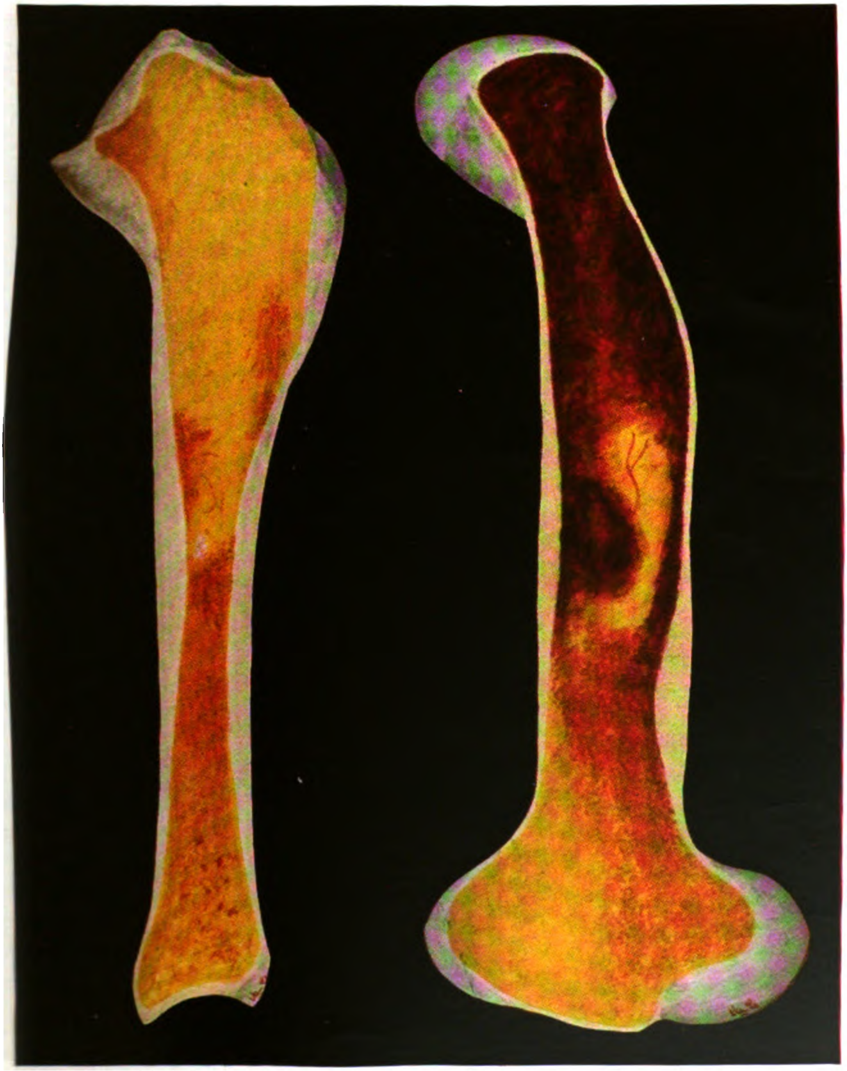


Plate No. III.
Longitudinal sections of the left femur and left tibia of No. 855.

color and slightly emphysematous on ventral border. The right lung is dark blue in color and somewhat edematous. The heart tissue is quite firm but of a pale color.

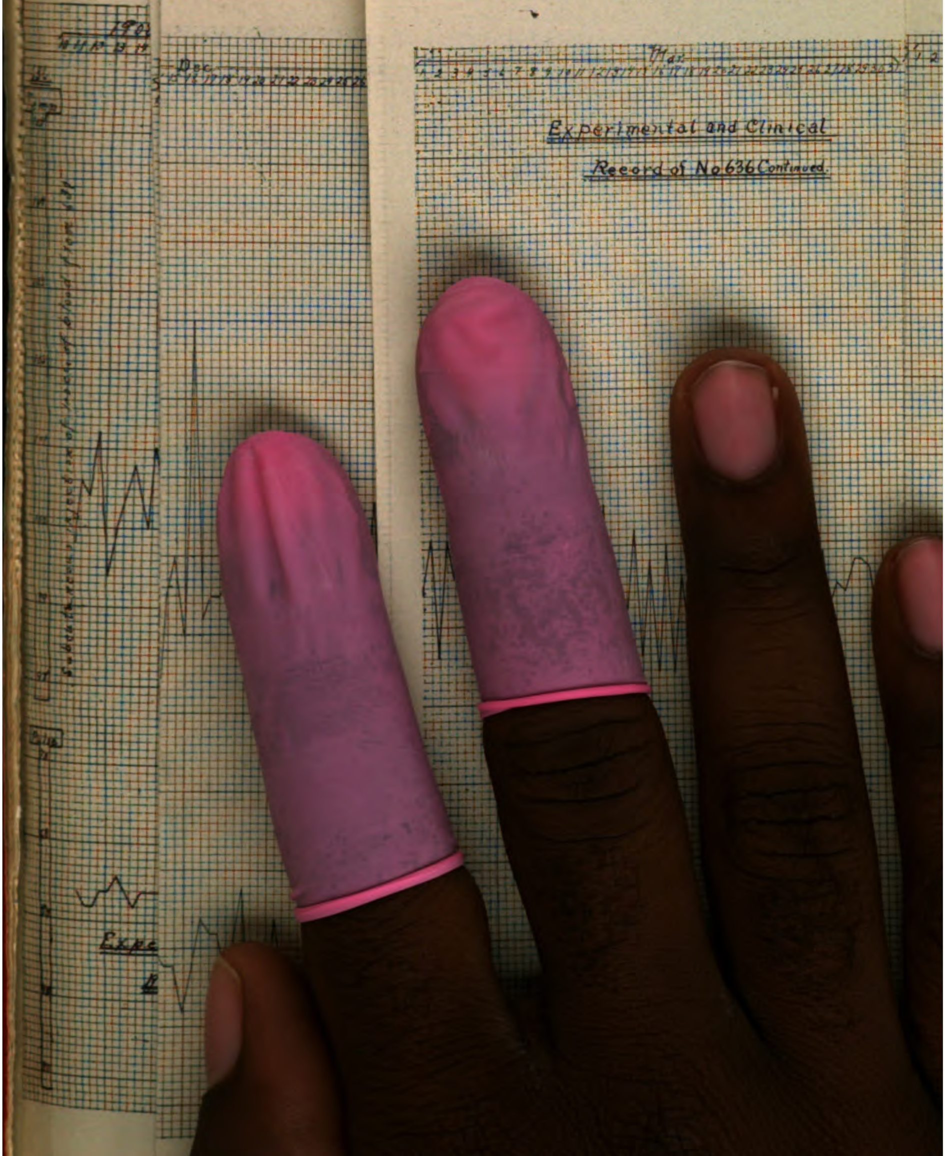
No. 855. (An experimental case infected by means of the blood of experimental case No. 636.) The carcass is very thin and there is a lack of subcutaneous, sub-mucous, sub-serous, and omental fat. The peritoneum is normal and contains a small quantity of fluid. The kidneys and pancreas are apparently normal, but the former show upon microscopic examination, a few, very slight and probably recent interstitial round cell infiltrations. The glomeruli are somewhat congested and a few tubules contain hyaline casts. The bladder contains about a quart of normal urine and has a normal mucosa. The external surface of the spleen presents evidence of a slight adhesive peritonitis, and shows numerous ecchymoses confined to its capsule. The liver aside of a pronounced adhesive peritonitis on its surface, has a normal appearance. The stomach contains about ten "bots" but is otherwise normal. The small intestines are normal. The mucosa of the cæcum showed a number of Sclerostoma, also three nodules (parasites) between the serous and muscular coats. The first and second sections of the large colon showed myriads of small round worms (probably S. tetracanthum) mixed with the contents. The third section showed several ulcers in the mucous coat, which were of a probable parasitic origin. The different lobes of the lungs contained numerous small nodules principally underneath the pleura, but few were scattered through the lung tissue. The pleura is normal. The heart has a normal appearance and does not show any microscopic lesions. All lymphnodes examined are normal. Bone-marrow changes are pronounced especially in the femurs. The proximal cancellated bone tissue is densely hyperemic and a good part of the fat marrow shows a change to lymphoid structure.

No. 857. (An experimental case infected by means of the blood of experimental case No. 636.) The carcass is poor, has very little adipose, but the muscles are normal in color. The small intestines and floating colon are normal, but the mucosa of cæcum and large colon is inflamed over a considerable area. Sclerostoma are present but not in large numbers. The spleen is normal but shows slight siderosis. The naked eye appearance of the kidneys is normal with the exception of small calcareous deposits being present in the medulla just outside the pelvis. Microscopically the kidneys show some capillary engorgement and areas of interstitial nephritis, but the parenchyma is fairly intact. In the region of the diaphragm and liver there is evidence of a considerable chronic peritonitis in the shape of numerous adhesions. Otherwise the gross appearance of the liver is normal. Microscopically the organ shows interstitial and intralobular round cell infiltration and some parenchymatous degeneration. The bone-marrow especially that of the femur shows areas of a dark red discoloration, the remainder being pale and very fatty.

No. 867. (An experimental case infected by means of the blood from experimental case No. 636.) The subcuta contains a yellowish, gelatinous substance, especially well marked on ventral portion of abdominal wall. There is marked evidence of an old adhesive peritonitis, both parietal and visceral. There is no excess of peritoneal fluid. The spleen is slightly enlarged and shows numerous hemorrhagic pin-head areas beneath capsule. Microscopically there is marked siderosis and slight hemorrhagic engorgement. Splenic lymphnodes are slightly hemorrhagic. The small intestines show a distinct, acute enteritis throughout, with the exception of the first ten feet of the jejunum. The bladder is devoid of urine, but contains a couple ounces of yellowish, brown, sandy sediment. There is also evidence of a slight cystitis. The kidneys contain a mucoid deposit, closely adherent to the pelvis, otherwise they appear to be normal to the naked eye. Sections, however, reveal pronounced interstitial lesions but the parenchyma is well preserved. The large and floating colons are normal but the mucosa of the cæcum presents slight petechiæ near the apex. The stomach contains a small amount of ingesta and presents a well marked gastritis. The visceral lymphnodes show a slight hemorrhagic condition. The liver has a normal size. Its capsule shows well developed fibrinous appendages, some penetrating into the liver structure. The border of right lobe shows a considerable hemorrhage. Histologically, this organ shows an interstitial hepatitis, well marked and of recent origin. There is a slight siderosis and the parenchyma is fairly intact. Both layers of the pleura show adhesive pleuritis. The lungs are collapsed, the right one showing hypostasis. The bronchial and mediastinal lymphnodes are hemorrhagic. The pericardial sack contains about 500 c. c. of a yellowish, red fluid. It is slightly adherent to the diaphragm. The myocardium shows small petechiæ, while there are very marked ones on the endocardium. The bicuspid valve has a marked hemorrhagic area extending throughout the entire valve. Microscopically the myocardium shows a beginning of brown atrophy with here and there a slight evidence of interstitial myocarditis. The marrow of the proximal extremity of the left femur is dark red in color, the marrow cavities being filled with an abundance of dark red pulp. The marrow of the distal extremity is pale, the pulp apparently being replaced by a fatty debris. The place normally occupied by the yellow marrow shows a large area of hemorrhagically infiltrated tissue. This dark red part shows an arrangement in foci. Each such focus is surrounded by a bright red zone, which is somewhat separated by an intervening light colored strip from the dark red structures. Of the right femur the upper extremity is like that of the left, while the lower also resembles the corresponding part of the left bone.

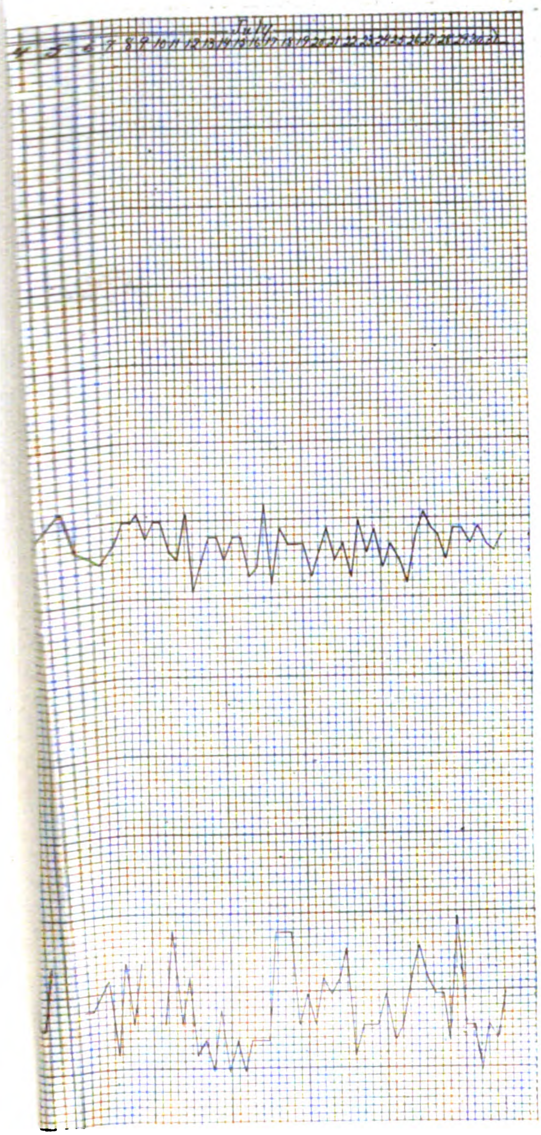
No. 902. (An experimental case infected by means of blood from experimental case No. 855.) The cavader is thin. The peritoneum shows a slight yellow tinge and is quite pale. The spleen is normal in size, but shows numerous slight, sub-capsular hemorrhages. The borders are slightly rounded and the organ shows a rather tense appearance. Splenic lymphnodes are somewhat edematous and enlarged. The liver is normal in size and appearance with slight adhesions to the diaphragm. The small intestines appear to be normal with the exception of several ecchymotic areas on the mucosa. The large colon presents a normal appearance. Its contents show several specimens of Sclerostomum equinum. There are numerous ecchymotic spots in the region where the parasites are found. Several small nodular enlargements were to be seen in the mucosa. The cæcum contained a markedly hemorrhagic area. The kidneys are apparently normal. The bladder contained about 500 c. c. of a straw-colored viscid urine. Its mucosa is slightly congested in the ventral portion. The heart muscle is quite firm and has a good color. The left ventricle presents a slight ecchymosis of the endocardium. A small hemorrhagic area is found on the auriculo-ventricular valve. The lungs show no changes and collapsed completely when the thorax was opened. The bone-marrow shows but very few hyperplastic areas.

No. 903. (An experimental case infected by means of the blood of experimental case No. 873.) The general condition of the carcass is good and all adiposa are well developed. The peritoneum shows pronounced visceral adhesions, especially on liver and spleen; the peritoneal fluid is normal. The right kidney is apparently normal; the left one is considerably congested (antemortem). The bladder is normal and contains 200 c. c. urine of an orange-yellow tinge (S. G. 1046, neutral reaction, contains a trace of albumen). The spleen is normal, with the exception of the adhesions noted above. The splenic lymphnodes are enlarged and hemorrhagic. The liver presents no changes, aside of the adhesions previously mentioned. The mucosa of the small intestines presents numerous fresh hemorrhagic areas and that of the cæcum, a few small ulcers, evidently of a parasitic origin. The first division of the



Experimental and Clinical

Record of No 636 Continued.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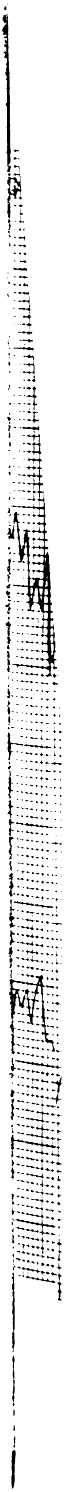
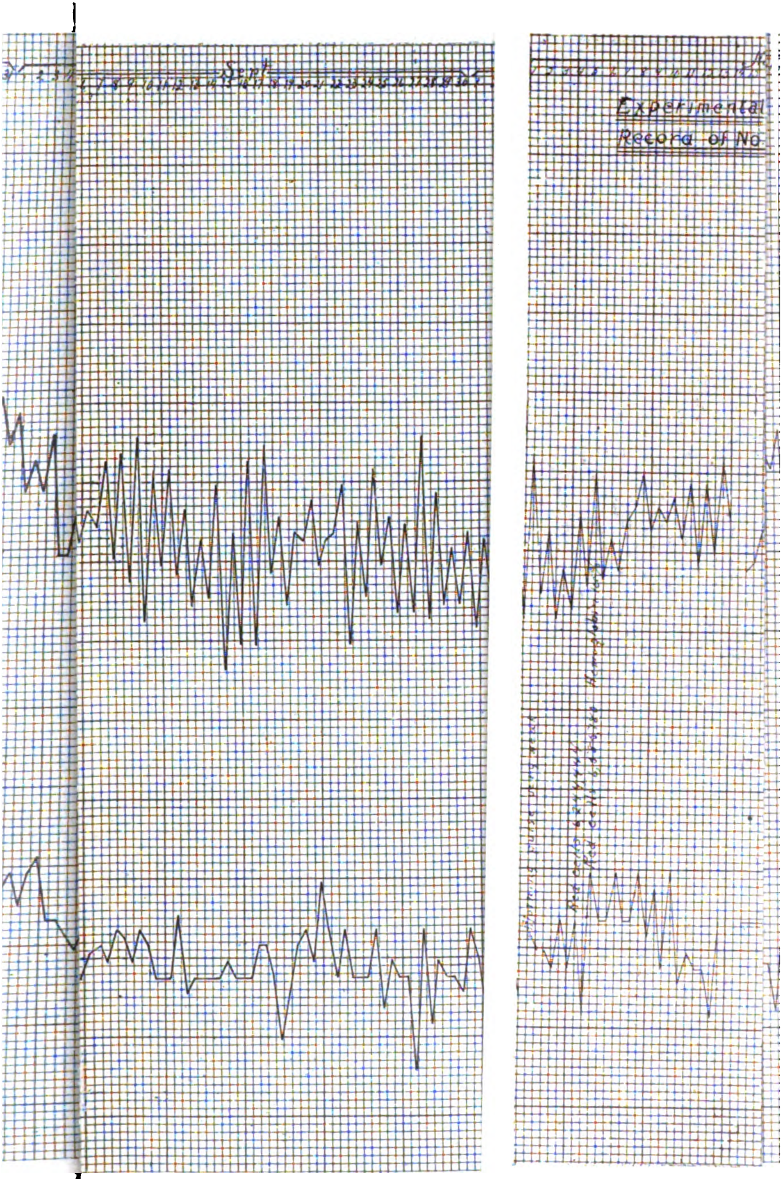
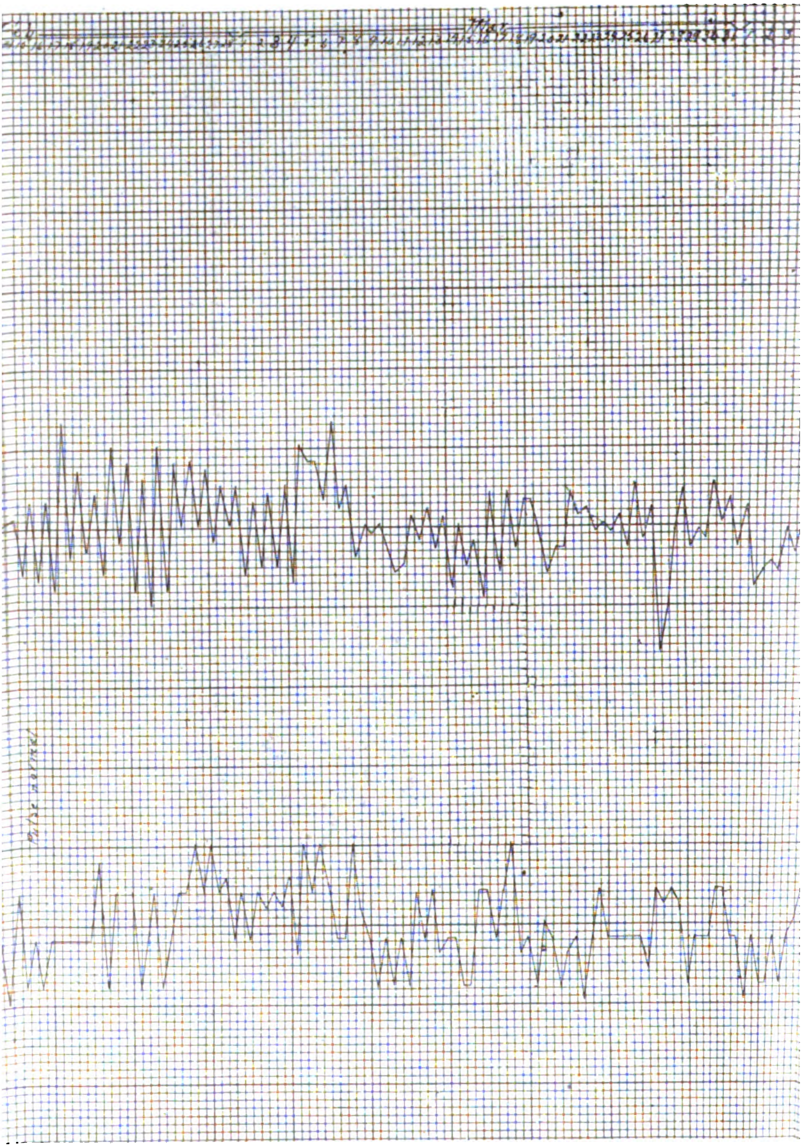
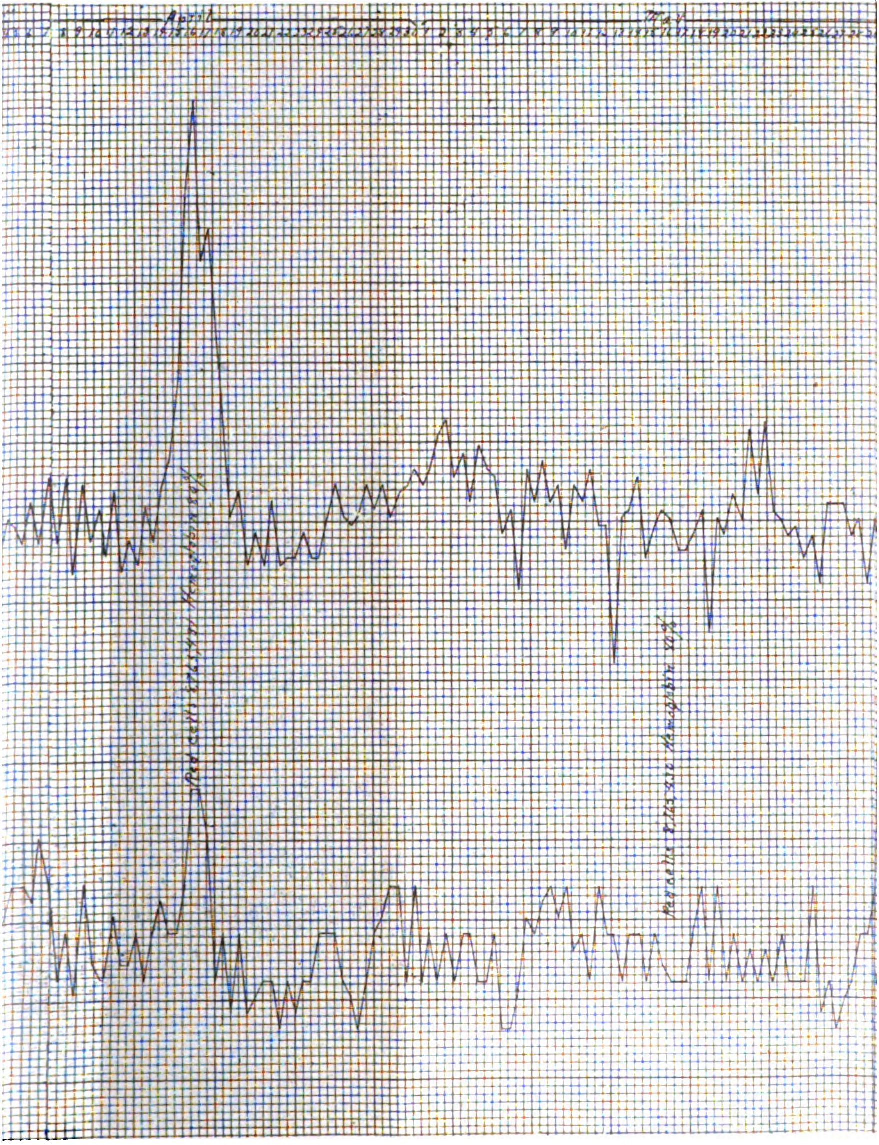
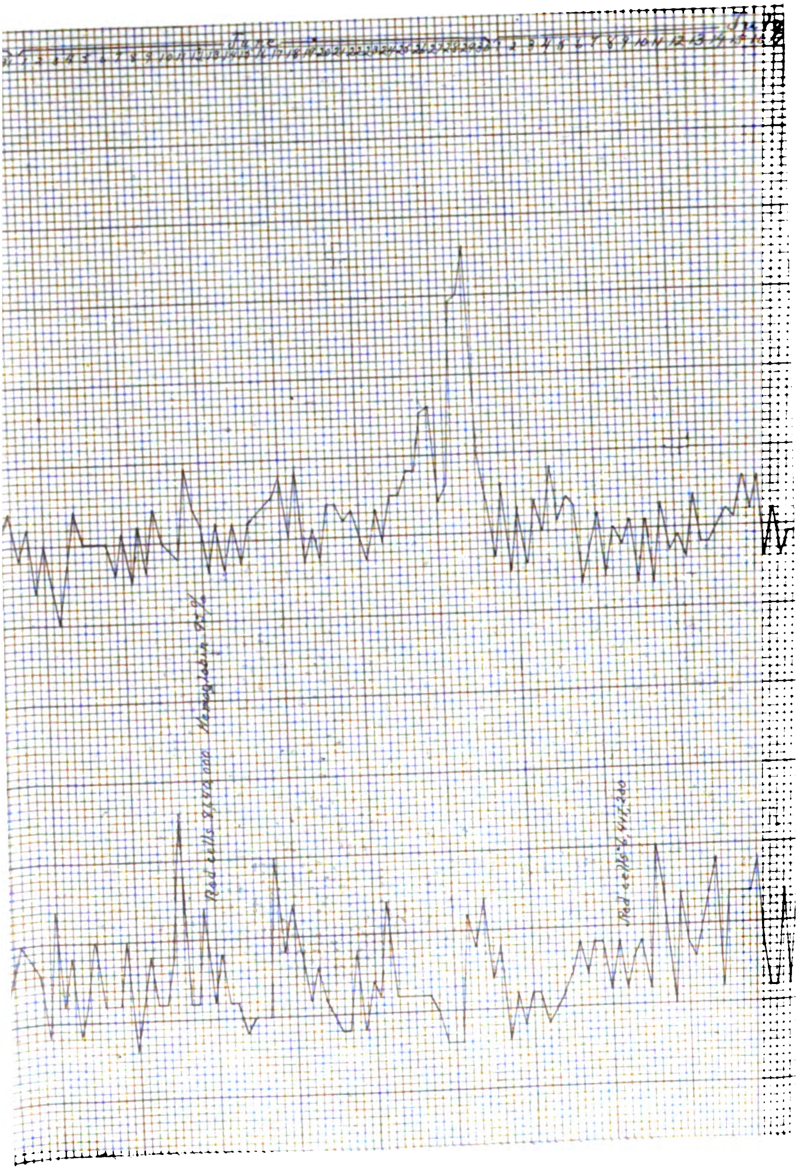


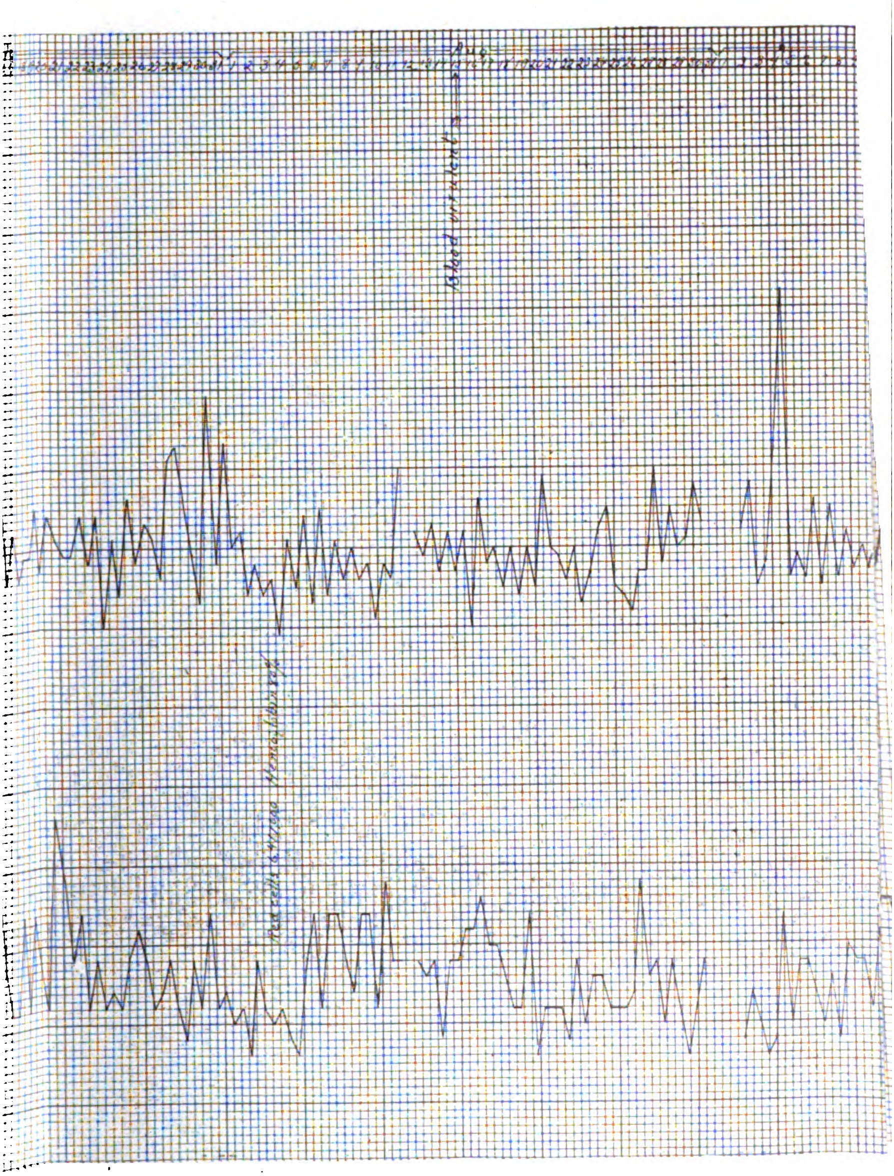

Sept.
Experimental
Record of No.
Morning pulse very weak
Red cells
Red cells
Hemoglobin

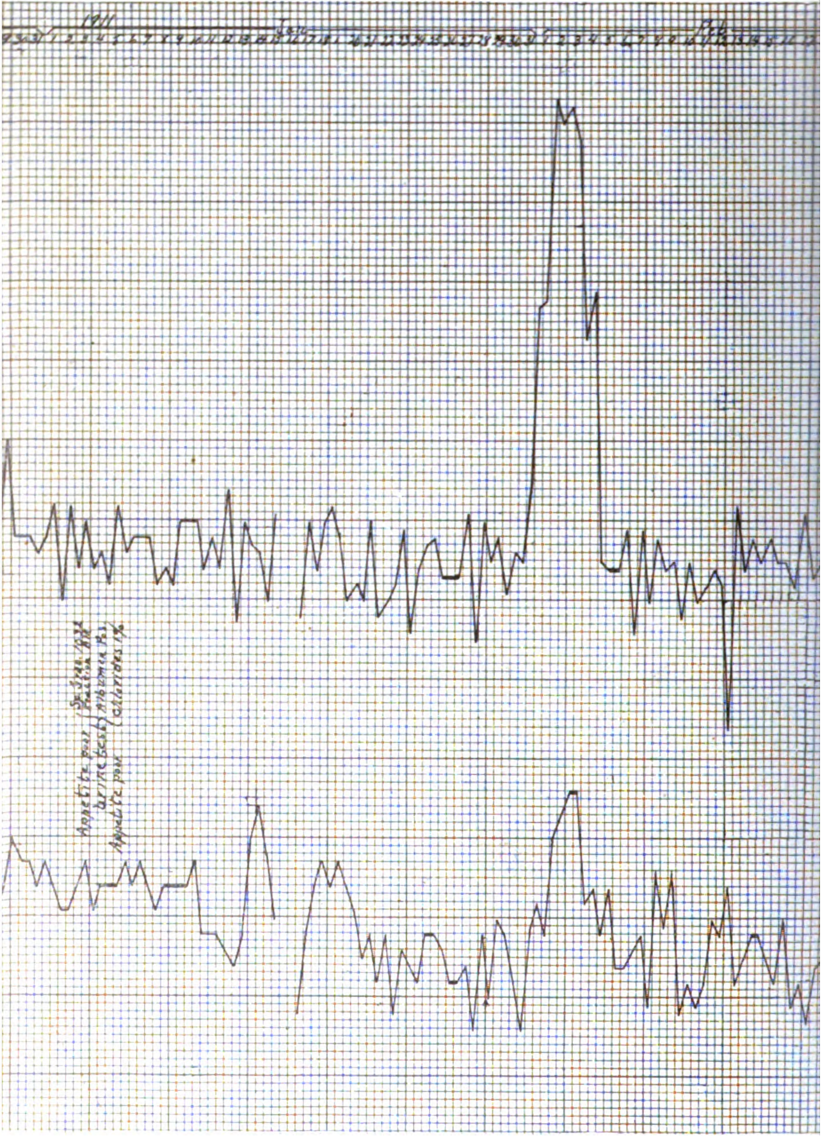
UNIV. OF MICH.

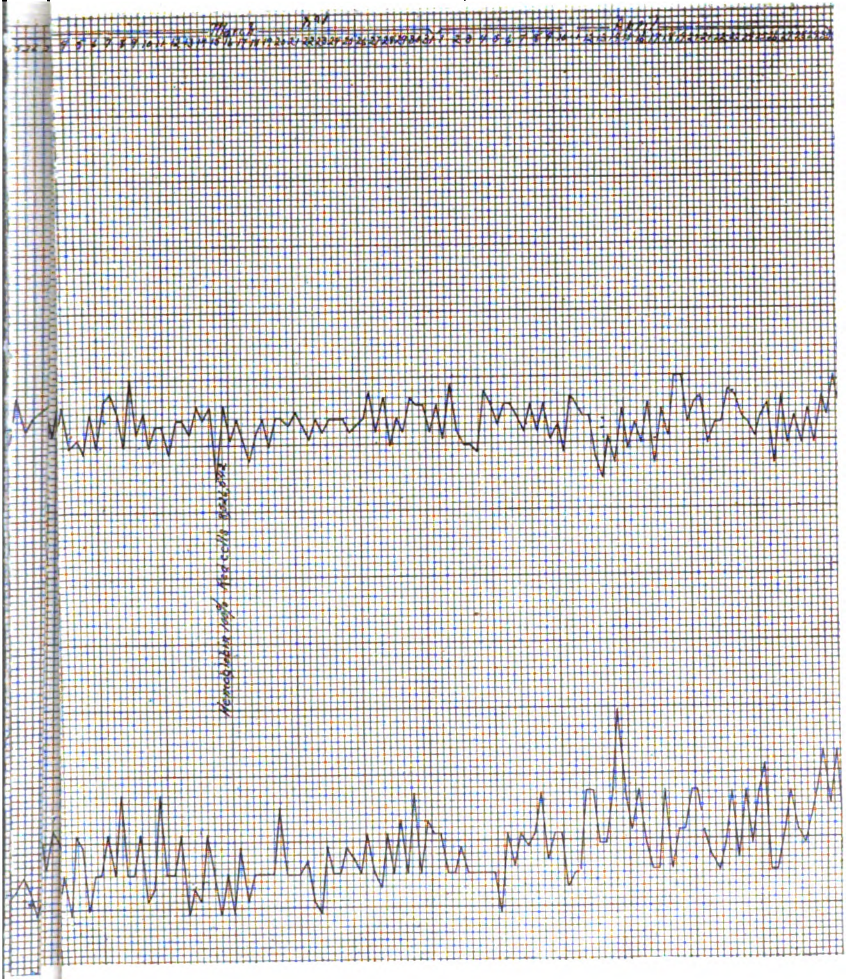

May

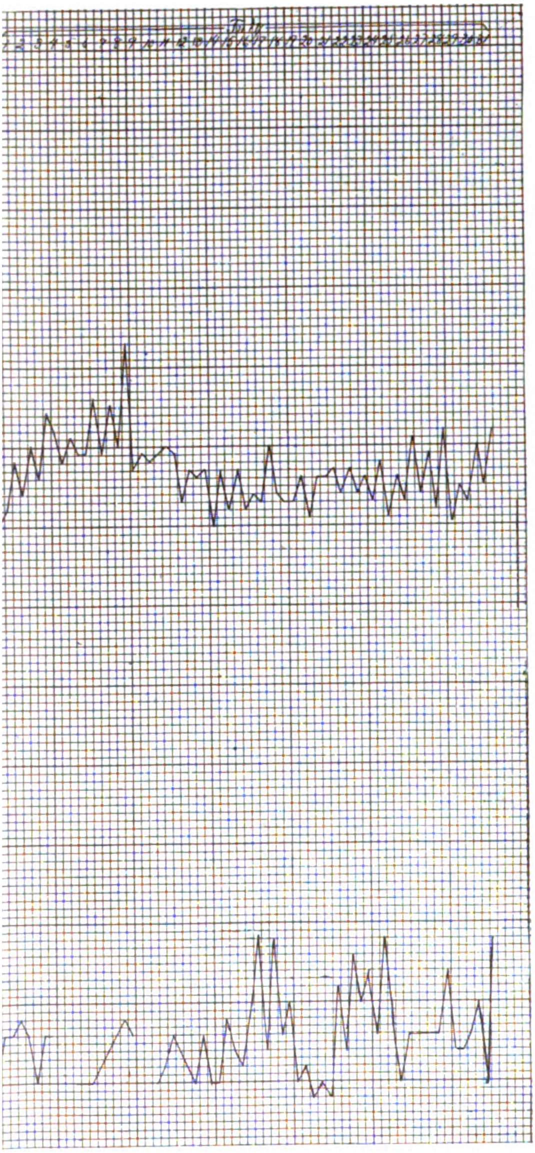

April
May
Red cells 6,765,491 Hemoglobin 84%
Red cells 8,165,336 Hemoglobin 80%


June
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
July
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Red cells 8,144,000 Hemoglobin 92%
Red cells 6,417,200


Aug
Blood virulent
Pus cells 6,111,000 Hemoglobin 80%


1911
Jan.
Feb.
Appetite poor
Urine test
Appetite poor
Sp. Grav. 1022
Reaction Alk
Albumen Pos.
Chlorides 1%


March
April
Hemoglobin 100% Red cells 8,526,000


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

large colon contained a great number of helminths (Sclerostoma). The apparently normal stomach contained a few "bots." Lungs and pleura are normal. No changes are seen in connection with the heart, but a few projecting calcareous concretions are attached to the intima of the common aorta just behind the valves.

Nearly all the visceral and body lymphnodes were slightly enlarged and hemorrhagic. Hyperplasia of the marrow is seen in the femurs and humeri while the proximal cancellated structures either are hemorrhagic or marked by small dark areas.

No. 642. (A field case purchased in the vicinity of Fargo, N. D.) There is an almost complete absence of subcutaneous fat. The musculature, although reduced in volume was normal in color. The lymphnodes lying on the cæcum are enlarged and surrounded by hemorrhagic areas. The mesocolic lymphnodes are enlarged and soft, but the mesenteric nodes are not involved. In the cæcum there are a few parasites (Sclerostoma) and at certain places the mucosa is ecchymotic, while near the apex, there are quite a few parasitic nodules in the mucosa. The kidneys are slightly enlarged, soft, pale and friable, but sections taken from those organs show a slight degree of interstitial involvement, a shrinking of the glomeruli and an intact epithelium. The spleen is normal in size, thin and flabby. Cutting through the organ, it seemed as if the spleen pulp was reduced, while the connective tissue elements were more conspicuous. The liver is normal in appearance. The lungs are poorly contracted, while the right anterior lobe is somewhat emphysematous. The heart was pale and soft, and its cavities filled with ante-mortem clots. The peritoneum showed evidence of chronic inflammation with an organized fibrinous exudate, more especially near the diaphragm. The anterior and posterior mesenteric arteries showed small aneurisms. In the bladder was found a small quantity of urine (S. G. 1025, acid in reaction and free from albumen).

No. 639. (An experimental case infected by means of blood from experimental case No. 637.) There is a reduction in adipose. The muscles are generally of normal color. The spleen is about twice the normal size, shows some infarcts and microscopically, reveals a moderate degree of siderosis. The kidneys are paler than normal and the naked eye appearance leads one to think of parenchymatous degeneration. Microtome sections, indeed, reveal the presence of a naked congestion of the medullary vessels. There is a very marked interstitial nephritis, accompanied by shrinkage and degenerative changes of the glomeruli, with thickening of the capsule. In a few of the convoluted tubules there are some signs of parenchymatous impairment and many of the straight tubules contain casts. In the liver interstitial inflammation is marked and a great number of leucocytes have infiltrated into the lobules. Siderosis is apparent throughout and the parenchyma shows some slight fatty changes. The large colon shows a few sub-peritoneal nodules, while a few specimens of Sclerostonum equinum are contained within. The anterior mesenteric artery shows a large verminous aneurism. The lungs are well contracted and normal, with the exception of a small area of solidification which has a softened area in the center. The heart looks normal, but microscopically a very slight degree of interstitial myocarditis can be detected. The mucosa of the nasal septum presents a large, gangrenous area. This ulcertation was apparently due to a deep necrosis and extending clear through the septum involves the mucosa of both sides to the same extent and in the manner that the affected mucous surfaces were directly opposite one another. A large eschar is still intact in the ulcer and represents the gangrenous mucosæ and cartilage. The edges of the ulcer were rather smooth and at places occupied by a softened mucosa, apparently becoming gangrenous by continuity. There is nothing to indicate malleus and a conscientiously carried out bacteriologic research confirms this statement. The sub-maxillary lymphnodes were somewhat enlarged, but neither softened or purulent.

No. 743. (An experimental case infected by means of the blood from experimental case No. 638.) The lungs are inflated and show numerous slight adhesions between the pleural layers. There is no liquid exudate in the cavity. The anterior half of the lungs are filled with solidified foci, the cephalic lobe being entirely solid. The ventral border also solid to a width of about two inches. The ventral border of the posterior lobe also contains many solidified foci and presents numerous ecchymoses beneath the pleura. Along the ventral border of the posterior lobe there are numerous small necrotic areas. The pericardium contains about one liter of a straw-colored exudate. The right side of the heart shows marked ecchymoses and the auricle contains a large ante-mortem clot, which extends into the ventricle. The left side shows no changes. Sections of the heart reveal a general cloudy change of the myocardium. The liver has a weight of twenty pounds, is somewhat congested and firmly adherent to the diaphragm. The posterior surface was likewise somewhat adherent to the stomach, which organ showed a corresponding inflammation on the external surface; but its mucosa showed no lesions. Liver sections showed a well advanced parenchymatous degeneration and some siderosis.. The intestines show nothing abnormal. The kidneys and bladder appear to be normal, although sections of the former show slight interstitial changes throughout. There is a small degree of arterial thickening, while the glomeruli are enlarged filling out the entire capsule. A very slight degree of parenchymatous damage may be mentioned. The spleen is quite flaccid, shows some necrotic areas and a moderate degree of siderosis.

No. 723. (An experimental case infected by means of the blood of experimental case No. 638.) The cavader is poor, but not emaciated, the muscles have a normal color. The spleen has a weight of four pounds, six ounces, and shows small hemorrhages under the capsule. Heart, kidney, liver, intestines and lymphnodes are normal in appearance. The marrow of radius and tibia is pale, deficient in coloring and is quite fatty. The same conditions prevail in the lower extremity of the humerus and femur, but the upper extremity of the femur is lightly red. The cancellated tissue of the proximal extremity of the humerus has a mottled appearance.

No. 816. (An experimental case infected by means of the simultaneous injection of the blood from experimental cases Nos. 637 and 638.) The subcutaneous connective tissues are poor in adipose, lemon-colored, while the musculature has a salmon color. All the mucosæ are blanched. The lungs are inflated and show petechiæ on pleura. The bronchial and mediastinal lymphnodes are normal with the exception of a certain degree of anthracosis. The heart has a par-boiled appearance with pronounced ecchymosis of the endocardium of the left ventricle. The kidneys are of normal size, but show dark spots on surface and their substance is rather friable. The large intestines show very numerous petechiæ, which are also visible through the mucosa. The liver is normal in size and shows a fibrinous exudate on the surface. The spleen is slightly enlarged and has a few petechiæ on the surface. Petechiæ are also seen on small intestines, mesentery and bladder. In the upper end of the femurs, the bone-marrow is red for a considerable proportion and this red marrow is sharply demarcated from the yellow parts. The marrow of the lower part is of a yellowish-white color and edematous. The humeri and tibiæ have a marrow like that seen in the lower part of the femur, but in that of the lower part of the radii, there is still a pink color present, although it is very pale.

No. 920. (A field case purchased in the vicinity of Kelso, N. D.) The carcass was poor but not emaciated. The quantity of adipose is small. The peritoneum is apparently normal and contains about one liter of peritoneal fluid. Pancreas and kidneys are normal in appearance. The bladder looks normal and contains about 200 c. c. of amber-colored urine

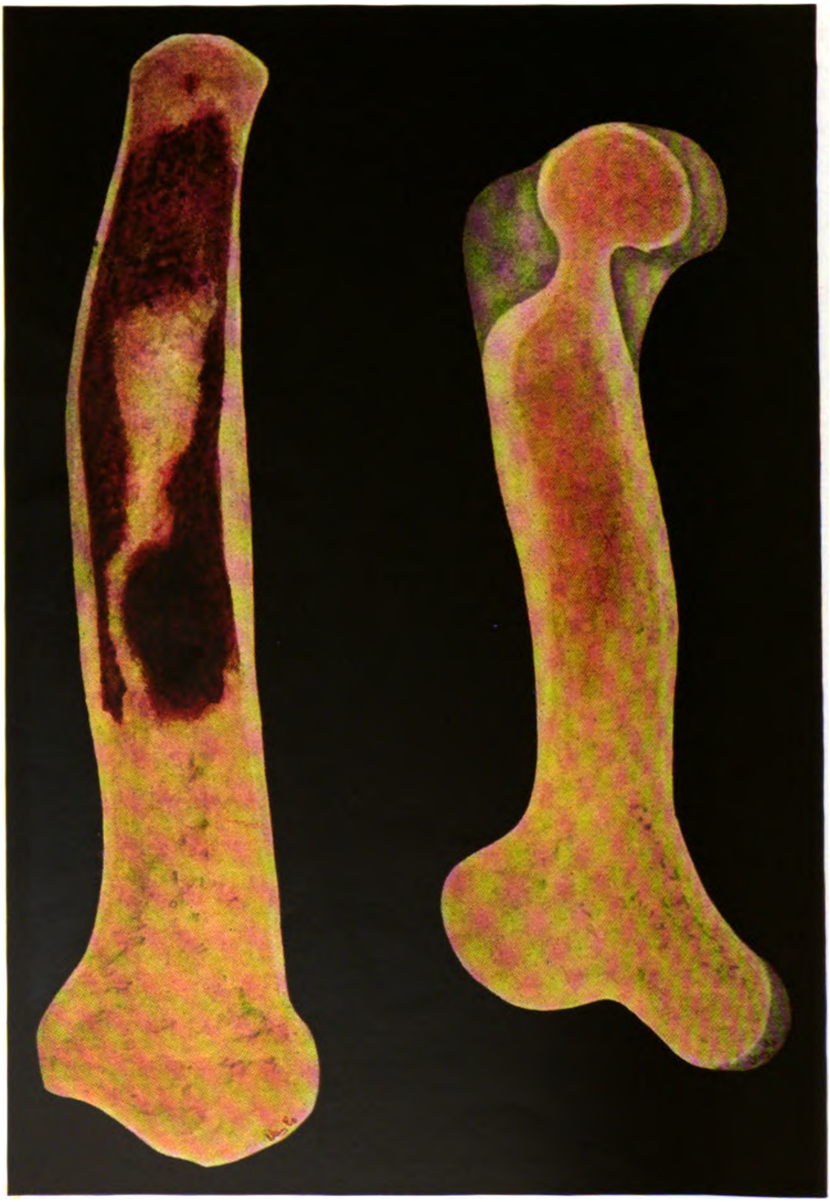


Plate No. II.
Longitudinal sections of the left femur and right humerus of No. 920.

(S. G. 1015, reaction strongly acid, albumen present). The spleen is of natural appearance but the splenic lymphnodes were enlarged, showing a hemorrhagic lymph-adenitis. The liver is enlarged to one and one-half the normal size, showing a marked adhesive peritonitis and pronounced siderosis. Under the microscope, the interstitial changes prove to be pronounced, there are granular changes in the parenchyma, while pigment deposits are seen throughout the sections. The portal lymphnodes are enlarged and hemorrhagic. There is a well defined verminous aneurism on the anterior mesenteric artery. The small intestines contained a small quantity of semi-fluid ingesta, through which were scattered about a dozen specimens of Ascaris megalocephala. The cæcum and large colon contained a large quantity of semi-fluid ingesta. The cæcal mucosa showed a few specimens of Sclerostoma. The floating colon is normal to the naked eye. The mesenteric lymphnodes were greatly enlarged and hemorrhagic. The normal stomach contains about six large "bots" and about a dozen smaller ones. The gastric lymphnodes present the same features as the mesenteric ones. The parietal pleura shows a well marked ecchymosis, the result of a pleuro-pneumonia. Both lungs show a well marked lobar pneumonia, the left being very extensive, taking in the entire ventral half. The pulmonary artery showed a marked thrombus. The bronchial and mediastinal lymphnodes are enlarged and hemorrhagic. The pericardial sac contained about one quart of fluid. There is subepicardial ecchymosis. The myocardium is pale, flabby, and apparently degenerated. Subendocardial ecchymosis is in evidence. The right heart is filled with an ante-mortem clot. The marrow changes are the same as in the other cases; there is hyperplasia of the fat marrow and hemorrhagic areas are noted in the other parts of the bone.

No. 930. (An experimental case infected by means of the blood from experimental case No. 919.) The cavader is thin and presents a scant amount of subcutaneous, sub-serous, sub-mucous, and omental fat. The peritoneum is apparently normal with the slight exception of some adhesions of the viscera. Liver, spleen and kidneys are seemingly normal. The bladder contained about one liter of lemon-colored urine and has a normal mucosa. (Urine: S. G. 1030, reaction neutral, albumen present). The stomach and small and large intestines are normal. There is a colony of "bots" in the stomach and the large intestines contain contain a few Sclerostoma. Lungs and pleura are both normal. The heart presents slight subendocardial petechiæ and ecchymoses, but is otherwise normal. The lymphnodes are apparently normal with the exception of the mesenteric ones, which are slightly edematous. The marrow of the bones shows some hemorrhagic infiltration and a few well defined hemorrhagic areas.

No. 921. (Field case purchased in the vicinity of Shelly, Minn.) The carcass is thin and shows a marked edema of the sheath, the lower abdominal and thoracic walls, between the fore legs and on the inner side of the thighs. The adiposa are reduced in volume and the subcuta shows a slight lemon color. The fairly well developed musculature suggests a lemon color. The peritoneum presents numerous fibrinous adhesions to the viscera and contains about one liter of a dark thin hemorrhagic fluid. The stomach is normal; there are not "bots" and the gastric lymphnodes are normal also. The small intestines offer no changes, but their lymphnodes are hemorrhagic. The large intestines are normal throughout. The heart is enlarged, flabby, and has a par-boiled appearance. There was about one liter of dark hemorrhagic fluid in the pericardial sac. There are subendocardial petechiæ near the columnæ carnæ of the left side and the auricles are filled with large chicken-fat clots. The kidneys are normal in size, but very pale, probably the seat of a considerable parenchymatous change. The renal lymphnodes are enlarged. The liver shows a post-mortem change, but is normal in size. The spleen is slightly enlarged and shows petechiæ under its capsule. The bladder contains about one liter of urine (S. G. 1012, and acid reaction and contains a

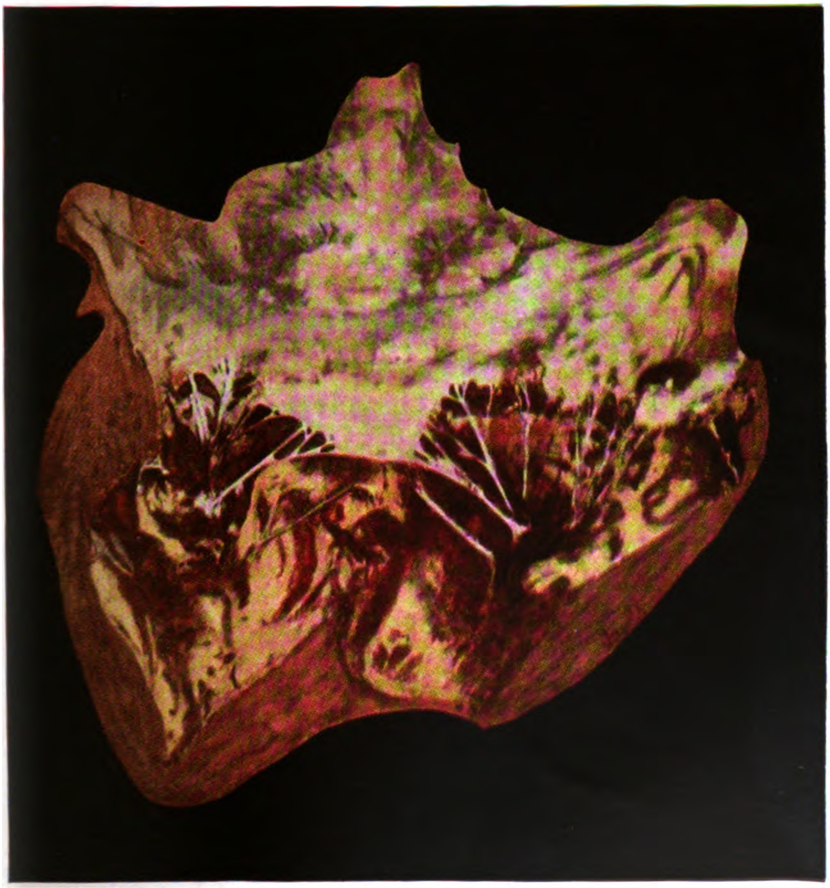


Plate No. I. Heart of No. 934.

trace of albumen). The upper part of the bone-marrow of the femur is of a deep hemorrhagic red. The marrow cavity contains fat marrow to one-half of its capacity, while the other half contains a hyperplastic red marrow. The extremities of the humeri are extremely pale and here and there show small hemorrhagic areas. The fat marrow also shows a few hyperplastic areas. In the tibiæ and radii, a uniform lemon color is observed.

No. 924. (An experimental case infected by means of the blood of field case No. 921.) The carcass is in fairly good condition. The panniculus adiposis is well developed and submucous, sub-serous, and omental fat is not materially reduced. The peritoneum, with the exception of some slight adhesions between liver and diaphragm, is normal throughout. The kidneys are both congested and the bladder contained about two liters of urine (S. G. 1020, neutral reaction, containing a trace of albumen). The liver has a normal appearance as well as the spleen. In the small intestines there are diffusely spreading hemorrhages, the duodenum showing a decided congestion. In the cæcum and large colon, the mucosa is almost a continuous hemorrhagic mass and the vessels of the sub-mucosa are heavily injected. With the exception of a few subendocardial petechiæ, the heart is normal for so far as naked appearances go. The lungs and pleura are normal. There is marked hyperplasia of the bone-marrow of the femurs, but in the other bones, this condition is less marked.

No. 934. (An experimental case infected by means of the urine of experimental case No. 924.) The cadaver is in fair condition, although there is but a slight amount of subcutaneous, sub-mucous, sub-serous and omental fat. The kidneys are slightly enlarged and show slight capsular and parenchymatous hemorrhages. The bladder contains about 500 c. c. of urine (S. G. 1024, reaction sharply acid, contains a considerable amount of albumen). The spleen is considerably enlarged and the pulp showed a blackberry jam-like color and consistency. The liver is slightly enlarged and wholly free from adhesions. The mucosa of the stomach showed marked ecchymoses. With the exception of a couple of parasitic nodules, the small intestines are apparently normal. The large intestines present a few parasitic ulcers to which a pair of specimens of Sclerostoma were attached. The lungs were normal. The heart shows subpericardial ecchymoses, myocardial hemorrhages and the endocardium in all compartments of the heart is covered by hemorrhagic areas. Most of the visceral lymphnodes and especially those of the spleen are enlarged and slightly hemorrhagic. The bone-marrow changes in this case are slight and consist principally of the presence of small hemorrhagic acreas.

Reviewing our findings made at autopsies and those reported by other investigators, it would seem that none of the lesions are such as deserve to be regarded as pathognomic. There are no changes which unmistakably bear the brand of identity. Almost any of the changes met with may be found in association with other diseases and in themselves are of but little diagnostic value, and hence they can only be used diagnostically as a certain link in a chain of evidence furnished by clinical, epidemiologic and experimental data. The features deserving the most attention are no doubt the petechiæ and ecchymoses of certain structures, lymphnode involvement, interstitial and parenchymatous lesions of certain important viscera, albuminuria, and the alteration of bone-marrow and the blood. We have refrained from discussing the latter in connection with the pathologic anatomy of the disease, preferring to do so when dealing with the clinical features of the disease. It is possible that the bone-marrow lesions constitute a valuable aid in the post-mortem diagnosis of the disease, but in view of the fact, that we know, comparatively so little of bone-marrow changes in connection with other diseases of the horse, or even under varying normal conditions, we would rather suspend judgment relating to their diagnostic value until the matter has been looked into more fully. The writers contemplate making some observations in regard to marrow changes in various conditions and hope to be prepared to place a proper value on those seen in "swamp-fever" in the course of the coming year.

Studying the clinical manifestations of the disease, we meet with a more or less constant series of symptoms, which are somewhat characteristic. Taylor (7) speaks of "swamp-fever" as an intermittent fever somewhat analogous to surra and characterized by anemia. The one case described by him has a slight attack of fever, was rested up and appeared at one time to have recovered. When driven, however, it appeared so sluggish, that it staggered when led into the stable. In addition to the staggering gait, the animal showed signs of laminitis. The weakness of the hind quarters remained a prominent feature in this case, but the appetite showed but little impairment. The animal soon commenced to lose flesh, the abdomen became tucked up. Taylor also speaks of a discrepancy existing between the height of temperature elevation and the increase in the number of pulse beats and regards it as "one very diagnostic symptom." In Taylor's case the mucosa became paler than normal, having a yellowish tinge, which became more evident as the disease advanced. The animal improved and relapsed several times.

The patients observed by Köpke (8) stood with their heads down in the manger and showed a rather capricious appetite. The conjunctiva was conspicuously pale without showing any yellow tinge. In the beginning of the disease, the pulse was relatively strong, but more frequent than normal (50-60 p. m.). The most pronounced symptom was the high body temperature which in nearly all cases was elevated from the beginning. (105.5°-106.7°F.). In the further course of the disease, the fever remained almost constant for eight to fourteen days. The heart function decreased in force, the pulse becoming weaker and its frequency ranging from eighty to one hundred beats per minute. At the same time the pallor of the conjunctiva became more marked. In the cases running a favorable course, the temperature receded gradually to normal in from six to eight days, and the animals made a complete recovery in from two to three weeks. In the more severe cases also, the temperature came down in from ten to fourteen days, but only to 102.2° F. to 101.1° F. The patients then became more lively, but the pallor of the mucosa and the cardiac weakness persisted and after an apparent improvement of from ten to fourteen days, another febrile attack with the usual accompaniments had to be sustained. This would happen three or four times within two or three months. During this time, the animals would lose considerable flesh. In many cases a severe diarrhea would set in. During the last stages of the disease, the animals would sway considerably with their hind parts and could no longer maintain themselves in the standing posture. As an accompaniment of the complete anemia of the mucosa and a high degree of cardiac weakness, marked edema of the dependant parts of the body would make its appearance and the animals, after an illness lasting from four to eight weeks, would succumb in a very emaciated condition.

As described by Torrance (9) the disease is essentially a fever of the remittent type characterized by progressive anemia, gradual emaciation in spite of a good appetite, edema, weakness and loss of power in the hind legs. Weakness is the earliest symptom, which is closely followed by uncertainty in the movements of the hind legs, which causes the animals body to sway the hind quarters. The appetite continues normally or is even increased. The pulse gradually assumes a greater frequency, running from 50 to 70 beats per minute and presenting a peculiar thrill as if the vessel were only partly filled. The temperature ascends to 103° F. or higher and shows considerable irregularity. The animal now becomes too ill for work and may receive some form of treatment. In spite of apparent improvements, which however, are only temporary, the animal becomes thinner, the mucosa becomes pallid on account of the profound anemia, while the edema of the dependant parts of the body makes its appearance. The pulse becomes more rapid and weak and the heart action labored. The skin is dirty and greasy to the touch and the animal has polyuria. Torrance also met sometimes with more acute cases in which the symptoms are presented in a more aggravated form and the animal dies in two or three weeks. The red blood count of Torrance's cases went as low as two millions. The corpuscles retain their form well and this author never witnessed marked poikilocytosis, although there has generally been seen a small proportion of megalocytes and microcytes. There was a marked increase in the clotting properties. In one or two acute cases, Torrance observed, what appeared to be debris of red corpuscles floating in the plasma. The granules were formless, irregular in size and had no power of motion.

Brimhall, Wesbrook and Bracken (10) write that in the Minnesota disease the onset was insiduous, but once developed, it was accompanied by a general weakness, slowly progressive, loss of flesh, periods of fever, followed by times of apyrexia, gradual emaciation, staring coat, a ravenous appetite, and sometimes by polyuria, as the most prominent symptoms.

The following symptoms are described by Rutherford (11) as the most prominent: progressive emaciation, edematous swellings of the dependant parts of the body, progressive pallor of the visible mucosa on which petechiæ may be occasionally seen. The peculiar soft, flat pulse is regarded as almost diagnostic, while the periodic rise and fall of the body temperature, ranging from normal to 105° F. is regarded as the most important of all symptoms. The appetite, while capricious, generally remains good until near the last. Lack of muscular control is common in the more advanced cases, but Rutherford ascribes this more particularly to the general weakness. Polyuria is frequently seen in the latter stages.

The ten cases reported by Béghin (22) all commenced by losing their appetite, then they became dull and still later they acted as if paralyzed. All animals sustained a considerable loss of flesh. They showed swelling under the chest and belly, while in the geldings the sheath became swollen also. The fatal cases went on to the extreme emaciation. The one case actually seen and examined by this author himself was very poor in flesh, hide-bound, with a staring coat and stood with its head down. The appetite was diminished and irregular. The mucosa are pale. The pulse is small and very much accelerated. The artery is soft, but the beats are regular in spite of those changes. There is a slight edema under the chest and the heart beats violently. A marked systolic murmur can be detected.. The respiration is more frequent than normal, but there is neither cough nor discharge. The temperature is 103° F. and weakness is a marked feature, the animal having difficulty in moving the hind legs.

The fundamental observations made by Carré and Vallée (28) deserve to be quoted quite fully. Their investigations led them to recognize three clinical forms of the disease; namely, the acute, subacute, and chronic types.

The acute type sets in suddenly. The animals become soft and lazy when at work. The least effort at pulling or speed causes the animals to blow or in some cases even to fall down. The appetite fails and the food is taken slowly. The conjunctiva is injected, edematous, yellowish with a red ground-color. Petechiæ of a translucent aspect are frequently observed. They are pink red, brownish or purplish in color and from 10-20 m. m. in diameter. A flow of tears is quite often seen. The temperature rises to 104°, 105°, sometimes even to 107.5° and generally keeps up until the end. The animals hold the head in a fixed position, the nostrils are dilated, and the facies reminds one of tetanus. Evidence of enteritis with diarrhea makes its appearance. The fæces are often reddish in color and would lead one to believe that they contain blood, if the spectroscopic examination were not negative in its results. In certain cases, however, the fæces are streaked with blood.

No respiratory disturbances are encountered. The pulse is soft, quite frequent (60-90 beats per minute). The cardiac sounds are accentuated. Marked edema is not encountered, only a simple swelling of dependant parts. The urine is abundant, generally deep in color and always containing albumen. In certain cases the albumen amounted to 14 grammes per liter. As a general thing urine does not contain blood corpuscles or hemogoblin, but granular and epithelial casts may be present.

The animals sway or take the position of a foundered horse. Movements are painful and the wabbling gait is a marked feature. Getting up is difficult, there being present a clear paresis of the hind quarters. There is a progressive emaciation and the extreme weakness and paresis of the hind quarters may be expressed by incontinence of urine. The coat is staring and the hairs of the mane and tail can be pulled out with extreme ease. Pregnant mares commonly abort. In this form of the disease, the course ranges from five to fifteen days, more often about eight days.

In this acute type, the changes of the blood are but little pronounced. There are no signs of anemia. Nevertheless, the blood coagulates but slowly. There is a rapid separation of the corpuscles, which have a brownish red tinge and which agglutinate, massing themselves in small agglomerations floating in a highly colored plasma, which frequently is opalescent.

The subacute type presents the same features as the acute one, but they are more or less attenuated and differently associated. Clear cut remissions are a distinguishing symptom of this form, a remission, which, when anemia does not happen to become apparent, would lead one to accept a real recovery from the disease. Carré and Vallée even saw cases which went along for eight months without presenting fever. Such recoveries, however, are more apparent than real, as the urine still shows albumen upon analysis and the conjunctiva is edematous. Blood examination reveals a marked anemia. The slightest work causes the animals to blow, while the heart beats become fast. The animals sweat abundantly and sometimes drop in an exhausted condition. In this form the duration of the disease varies very greatly, ranging from a few weeks to several months.

The chronic type is characterized by the symptoms of an extreme anemia. The patients become soft, lazy, the appetite indifferent and capricious, the coat rough and staring, while the hair of tail and mane can be pulled out with ease. The mucosa are pale and the temperature is most frequently normal; there are intermittent attacks of fever, but they are not frequent. The animals are soft and weak. The pulse is soft, frequent, unequal and the artery is flabby. Sometimes a transitory diarrhea is observed. Edema of the dependant parts is seen and the gait is wabbly, stumbling, and arising is difficult. The urine is abundant and more often contains albumen. The anemia is progressive, the blood coagulating poorly, forming a soft small clot. Sometimes, even it is difficult to check hemorrhage in patients. After more or less frequent remissions the animals die, either in one of the exacerbations or succumb to the final stage of anemia.

Changes in the blood are never absent and pertain to both plasma and formed elements. The plasma is but very little coagulable, it is over-colored, of a deep yellow or greenish tint, very often dichroic, especially so in the acute cases and during the acute exacerbations of the chronic cases. The erythrocytes are friable and readily agglutinated. They are irregular in size. They are poor in hemoglobin and fragile. Crenation is very commonly found. The red corpuscles, after being stained with the basic aniline dyes enclose a body comparable in shape and color to a piroplasma.

The red cell count varies according to the type of the disease and the time of the examination. In the acute form, when the signs of anemia are masked by other symptoms, there already is a notable reduction in the number of cells. From the tenth or fifteenth day, the cells fall from one and a half million to two millions below the normal figure (about seven millions). At the time of death in the acute cases, the count only runs to four millions, in the subacute cases about two to two and a half million, and in the chronic cases the count will range from two to four millions, according to the condition of the patient. In some cases it will fall to one million. The leucocyte count does not show great deviations, there commonly being a slight leucopenia.

As seen in Nebraska by Peters (26) the disease is initiated by a recurrent fever, which is followed by weakness. The mucosa of mouth and eyes become very pale. A staggering gait is noticed as the disease progresses. The appetite is retained but the emaciation is progressive. The temperature becomes higher, ranging between 103° F. and 106° F. Temporary improvements were observed. Diseased horses usually live from two to three weeks, although Peters mentions some cases, which lived three months. Edema of the dependant parts of the body and petechiæ on the mucosa were observed. Polyuria is spoken of as a symptom of a serious condition. The blood count in field cases amounted to 1,800,000 to 2,000,000 red cells per cubic m. m.

Ries (27) does not regard the clinical picture as absolutely uniform. In certain subjects the disease runs its course without fever. The appetite is retained or diminished, while the strength becomes reduced. There is shortness of breath and the animals break out in sweat. Along with the presence of those conditions the anemia already is quite evident; the mucosæ are pale, white, and the pulse is weak, thready, while the heart sounds have acquired a metallic ring.

In other cases no alarm is taken before the appearance of the edema of the abdomen and the limbs. This form is especially seen during summer and early fall and on farms where there is a short supply of oats. In another form of the disease, albuminuria is seen, aside from a notable increase in the rate of respiration and a fever which fluctuates around 104° F. This albuminuria may be pronounced and exhausting in some cases, while in others the albumen only occurs in traces. The animals continue to eat but waste, as it were, before one's eyes. The mucosa are not yet blanched but become paler. The eyes present a peculiar aspect, they are bright, feverish with the bulbs retracted, the eyelids participating in this movement. In the advanced stages, the patients move about with difficulty, sway to and fro, and threaten to fall. The limbs become edematous as well as the lower parts of the body. The horse no longer lies down, but when he does so in from five to ten days, he goes down for good.

The symptoms named by Charon (34) are a rather sudden loss of flesh, softness when being moved, swaying of the hind quarters, a pale yellow color of the conjunctiva, muffled heart sounds, arterial depression, venous pulse, a well marked reduction of the blood cells and an irregular but rather high temperature. The appetite, at first capricious, becomes better, the animal eating abundantly. The hair coat was not bad and the conjunctiva yellowish, but neither infiltrated nor oily. In Charon's case there was no edema of the sheath, the abdomen, the chest or the hind limbs. At no time was there polyuria or albuminuria.

Ostertag (35) elicited the following description of some cases from an owner, who in the space of five years has lost some twenty horses with the disease. The first phenomena noticed was a knuckling of the hind legs, while in the course of eight days, the animals would be tired and unfit for work. They would lose flesh rapidly and in a high degree. The mucosæ would be yellowish-white and periodically the patients would show a high fever. A few animals also presented edematous swellings of the lower part of the chest and the sheath.

Among the most conspicuous symptoms, Francis and Marsteller (42) mention: progressive emaciation without any apparent cause, polyuria and a peculiar weakness of the hind quarters, which has given the disease the local name of "loin distemper." There are periodic attacks of fever lasting several days to a week or more; the temperature ranging from 103° F. to 107° F., and being followed by a drop to sub-normal, ranging from 95° F. to 98° F. There are remissions in the course of the disease, even apparent recoveries. The mucosæ are very pale, often of a yellowish or rusty color, while petechiæ may be observed on the conjunctiva as well as a dribbling of a bloody serum from the nostrils and anus. The skin becomes dirty, the eyes are sunken and there is a dribbling of urine with relaxation of the sphincters. Notwithstanding all this, the animals will eat ravenously until the last. The authors did not observe any nervous disturbances. They found anemia to be present. Some of the erythrocytes being abnormally large, while others were small. Nucleated cells were but rarely encountered.

Hutyra and Marek (69) recognize two forms of the disease. The acute form is ushered in by well marked signs of sickness. There is a pronounced dullness and general weakness, so that the animals easily tire and even fall during exertion. The weakness is most plainly seen in the hind quarters. Fever is simultaneously observed. This reaches its maximum height in from two or three days (104°-107°F.). It may remain constant until death or resume a resistant character. The pulse frequency is increased to 60-90 beats per minute, while it becomes weaker and softer, the heart impact being increased in strength. The conjunctiva is somewhat puffy, diffusely red in color, with a yellow tinge and on which irregular hemorrhagic areas are not rarely seen. The nasal mucosa also is reddened and shows petechiæ, especially on the lateral wall of the nasal cavity. Not infrequently, this is accompanied by a scant serous, sometimes reddish nasal discharge. A cough is sometimes noticed. There frequently is diarrhea, the dung sometimes being tinged with blood. Urine is frequently voided and contains albumen, of which the quantity may amount to 1.5%, as well as granular and epithelial casts. The appetite is suppressed from the beginning. A progressive loss of flesh, which may make such a headway, that in a few days the animals lose from one-fourth to one-third of their body weight. Slight edematous swellings of the dependant parts of the body were only rarely observed. The coagulability of the blood is lessened, the serum appears dark yellow or even somewhat greenish and dichroic. The number of erythrocytes lessens the duration of the disease. The duration of the acute cases ranges from 5-15 days, but may be extended to from three to four weeks.

Hutyra and Marek's chronic form of the disease is characterized by periodic attacks of fever and evidence of anemia. The occurrence of albuminuria is not constant and when present during the febrile attacks it is only slight. In this form edematous swellings are not rare. Nutrition is reduced from the beginning or remains satisfactory in those cases which are marked by a slow progress of the disease. Loss of flesh occurs sooner or later. The duration of this form of the disease extends from one to several months and may drag even over a few years.

Mack (50) speaks of acute, subacute and chronic types of the disease and states that they are not separated by a hard and fast line. The acute type comes on suddenly. There is an initial dullness, followed by prostration and high fever. Heart action is more powerful and frequent than normal and is accompanied by venous regurgitation. The conjunctiva is injected, yellowish and deep red. Loss of nerve and muscle force becomes remarkable as the disease progresses. Emaciation is rapid. The temperature although variable is high (105°-107° F.) with frequent irregular remissions. Cardiac impact is conspicuously increased, but in a few cases the heart is weak. The pulse is rapid, soft and compressible. Edema of the dependant parts of the body and enlargements of the lymphnodes are seen, but not constant in its occurrence. A blood stained, watery fluid frequently drops slowly from the nostrils. The fæces are often streaked with blood. Exertion provokes dyspnoea and palpitation of the heart. In cases lasting more than five or seven days there is a reduction in the hemoglobin, as well as in the corpuscles of the blood, but otherwise those changes appear to be insignificant. The number of leucocytes generally remains about normal.

The subacute type, spoken of by Mack, resembles the acute, but may be more insiduous in its onset. Its course ranges from a few weeks to several months and is marked by periods of apparent convalescence and subsequent exacerbations of the disease. A high, irregularly remittent, fever, a progressive anemia, a rapid emaciation, prostration, cardiac weakness and edema are characteristic features of this type of the disease. While the temperature may rise as high in this type as it does in the acute one, the periods of remission are longer. It rarely reaches the normal point and a greater irregularity is encountered. Locomotor, respiratory and cardiac difficulties become pronounced and are aggravated by exertion. Respiration may become labored. A venous pulse is noticed and the arterial pulse is soft and compressible. The lymphnodes may show enlargement. During the periods of high fever, the appetite may be interfered with, but otherwise it is keen enough.

In the chronic type the duration is longer. There are occasional slight febrile attacks, a weakened heart, jugular pulse and more or less loss of flesh and energy. Anemia is not marked until the later stages. In spite of temporary improvements a fatal issue is almost certain.

Whitehouse (56) recognizes several types of the disease. Those of the anemia type will run a very slow indefinite course. There will be a slight and gradual loss of flesh, with a staggering or swaying gait. The mucosa are pale. A constant and voracious appetite is invariable in this type and is accompanied by considerable thirst. There is generally a slight rise of temperature, but not over 103.5° F. The pulse runs from 50-70 beats per minute. As the disease advances, polyuria develops. The various symptoms gradually increase, the duration of the disease covering from three weeks to six months, the animal wasting away to a perfect skeleton.

Another type is mentioned by Whitehouse as the edematous one. It closely resembles the anemic one and is very nearly as common. Dropsical swellings appear early in the disease, beginning with a small pad at the brisket and a slight enlargement of the extremity of the sheath. These edemata, may increase to a great size and the skin covering them may exude serum. The legs may swell, but do not often do so. Temperatures up to 104.5° F. are occasionally witnessed.

A different type is the one showing intermittent fever. In this type the initial temperature may suddenly run up to 107° F. After three days of illness the normal may again be reached. Twenty-one days later there is a repetition of the occurrence and after twenty-one days more another attack occurs. Whitehouse observed two such cases, one completely recovering after a third attack, and the other one succombing, while the third attack was in progress. This author also speaks of the bronchial type and calls it puzzling. His observations on this type are limited. The cases which he saw were only very slightly wanting in flesh and "appeared like animals left with a bronchial thickening after influenza." A fulminating type is mentioned by Whitehouse.

In a more recent Canadian publication, McGilvray (64) dwells upon the tendency to apply the name of "swamp-fever" rather promiscuously to a considerable variety of horse diseases. He recognizes three typical entities, which are more often covered by the name of swamp-fever and calls them: I. Swamp-fever; II. Typhomalarial fever; and, III. Low fever. No. I is characterized by its insiduous and chronic course. remittent fever, pronounced anemia, associated with a steady, progressive emaciation, in spite of a well maintained and frequently voracious appetite. No. II is an acute or subacute affection of horses characterized by its sudden onset. There is an extremely high initial temperature, marked injection of the visible mucosæ, which later become icteric. There always is a marked disturbance of circulatory functions and extensive edema of dependant parts. A critical polyuria and diarrhea precede dissolution. No. III is distinguished by slight elevation of temperature, usually maintained, marked unthriftiness, lassitude and incapacity for work. The visible mucosæ are congested and frequently icteric. The appetite is capricious. Edema of the sheath is noticed. Polyuria is always more or less in evidence. The bowel function is irregular, the fæces frequently being coated with a slimy mucus.

Mohler (52) describes the disease as characterized by a progressive, pernicious anemia, by remittent fever, polyuria and gradual emaciation, in spite of a voracious appetite. This stage is followed closely by a staggering gait, swaying, uncertain gait, the hind legs being most affected. Weakness and tenderness in the loins are also mentioned. The pulse increases in rapidity and may run as high as 70 beats per minute, although weak, stringy and intermittent. The temperature may rise to 103° F. or higher, remaining high for several days and then dropping to rise again at irregular intervals. Toward the end of the disease, the temperature occasionally remains persistently high. Temporary improvements are noticed. Albumen appears in the urine in the advanced stages. Mohler occasionally observed a slow dripping of blood-tinged serum from the nostrils as a result of the oozing of thin blood from the mucosa.

Our own observations tend to show that fever is perhaps the most constant symptom mentioned in connection with the disease. It is always more or less irregularly remittent or intermittent in the field cases, the range of temperature commonly lying between 101° F. and 104° F. Towards the last it may have a tendency to be more constant, although this feature is not to be depended on as of constant occurrence.

In the experimental cases, it is the first of all symptoms and in quite a number of cases about the only one sufficiently pronounced to have a diagnostic meaning. In most of those cases it makes its appearance after periods of incubation varying from 6-21 days, according to the method of infection practiced. After intravenous injection, for example, the incubation period will be found to be shortened when the same virus is used. It will be somewhat longer after subcutaneous injection, while when the virus be given by the mouth, it will be still more prolonged. In general the period of incubation is longer when urine is used for infecting purposes than when blood is employed. It is, of course, not possible to fix the period of incubation definitely as variations in the virulence of blood and virus and the susceptibility of the experimental horse used are factors over which we have no control or which cannot be estimated. In the greater number of our cases we have found that when using fresh blood as a virus and injecting it subcutaneously in quantities of 60-120 c. c. we may expect the initial temperature rise in from 12 to 14 days. In such cases it sometimes happens, that the temperature rises to about 105.5° F. and then again drops down to normal for 12-24 hours, after which there is a steady increase in temperature, which reaches its height in from 2-4 days. The maximum temperature will usually amount to from 104°-107.5° F., but will not long remain so, as in a day or two, it will gradually go down either to normal or nearly so. This initial attack in most cases will last from four to ten days. In a few cases, the remission or intermission is of but short duration and is followed immediately by periods of more or less fever of indefinite duration. Such cases may run an acute course and carry an abnormal temperature until they die, while in other cases the fever may recede gradually after having lasted for several days. In most of our cases, the first months of infection witness a number of well defined fever exacerbations, separated by remissions and intermissions. At first they are apt to succeed in rather rapid succession, but as time goes on they become divided over greater periods. In the further course of the disease, as induced by experimental infection, there will be noticed periodic rises often after rather markedly regular intervals (See chart of No. 636), varying from 30-60 days. In some of the cases this feature kept up for two years, although the fever periods occurred at greater intervals after the first year. In other cases the temperature phenomena did not reappear after a year, while the virulence of the blood persisted for much longer.

The pulse rate is often influenced by the temperature and to some extent the curves show some parallelism. In anemic field cases of long standing the pulse is soft and thready, conveying the idea of swishing through the palpating finger. In more vigorous experimental cases, the pulse is more voluminous and but for the increased frequency does not differ much from the normal. Towards the fatal termination, the pulse becomes smaller, weaker and at last imperceptible. In all cases, with the possible exception of the more vigorous experimental cases, during the fever intermissions, the frequency of the pulse ranges between 55 and 65 beats per minute and may even reach from 90-100, or even more towards the final issue.

During the latter stages of the disease are changes of cardiac origin noticed. The impact is increased in force and may be accompanied by a churning sound, when pericardial exudate be present. An anemic bruit has been heard in some old field cases but is not a constant feature.

No respiratory changes have been noticed, which could be attributed to specific changes. In one of our field cases there was a concurrent pneumonia, with the ordinary symptoms of respiratory distress. In some cases there, of course, are respiratory disturbances incidental to cardiac or general weakness. In one of our cases there was a foul smelling nasal discharge due to extensive necrosis of the septum nasi.

During the febrile attacks dullness is a noticeable feature. The animals will stand with heads down into the manger or will hang back on their halters, as if wishing to support themselves in that way. In not a few of the cases, however, the fever exacerbations are not accompanied by any marked features and the rise of temperature and a little higher respiratory frequency are the only symptoms presented.

Under the conditions just mentioned, the appetite is usually reduced or entirely suspended. An idea prevails that in "swamp-fever" a normal or even an abnormally increased appetite is a constant feature. This is not so, as we have seen in many cases of the disease and especially during the febrile periods, that the appetite shows the same irregularities that it does in other febrile diseases. It is, however, true that in many of the chronic and anemic cases, a voracious appetite is a notable phenomenon and as such cases are probably the only ones usually diagnosed, we cannot wonder that an increased appetite is so often mentioned as something characteristic of the disease.

Weakness and lack of muscle tone is a prominent symptom in the anemic cases and even in the cases running the course without anemia, it is not infrequently a marked feature. The animals readily tire and blow, when exercised, they will knuckle over and stumble when moving and they present a well marked swaying, wabbling motion with the hind quarters, which seems to be the principal seat of muscular weakness.

Loss of flesh usually accompanies the febrile attacks and in quite a number it is progressive, the animals reaching a stage of extreme emaciation. Affected animals will frequently present a dull, staring coat, while the condition known as hide-bound usually prevails whenever emaciation is present. In other cases the state of nutrition improves during the non-febrile intervals, but when anemia becomes a feature, emaciation becomes a more or less constant phenomenon.

Edema of the dependant parts of the body, such as the lower thoracic and abdominal wall, the sheath, the limbs, is a common feature. It is more commonly seen toward the latter stages of the anemic cases, when it is due to the blood changes, combined with cardiac and probably also renal insufficiency. We have also observed marked edema, however, in the acute experimental cases, in which anemia was not a feature and in which the blood count even ran higher, than what is usually considered normal.

Anemia was certainly a more or less marked symptom in all but one of the field cases which have thus far come to our attention. The visible mucosæ are pale, even blanched, and the blood count will reveal a sub-normal number of red cells, usually ranging between two and four millions, although in one of our field cases, the count amounted to less than a million. In the experimental cases, anemia is by no means a constant feature, in fact, it was only in a few cases that artificial infection expressed itself by a marked anemia and several of the cases went to a fatal termination, with a normal blood count or even with a number of erythrocytes considerably above normal. The hemoglobin percentage is often reduced and this reduction is frequently greater than the degree of anemia would indicate.

Not uncommonly the blood clots but slowly and occasionally separation of clot and serum is imperfect. In such instances, the cellular constituents of the blood have time to settle to the bottom of the vessel before the entire contents are changed into a rather soft coagulum. The serum frequently shows a high color, sometimes a greenish cast. Occasionally there is a tendency on the part of the erythrocytes to clump together, so that the thorough mixing preparatory to counting becomes either difficult or impossible.

The changes in the corpuscles are not very marked. The erythrocytes are somewhat fainter in the anemic cases and may in the same blood, show a more or less conspicuous variation in size. Crenation is not uncommon, but typical rouleau formation is not often seen. A slight poikilocytosis has been observed in one or two cases only, but in none of the cases examined by this department were nucleated erythrocytes found. As far as our cases go, the blood always contains the specific virus of the disease, but a search for visible parasites which could possibly be associated with its causation always resulted negatively. In some of our cases bacteria were found in the blood, but there was no constancy as to the species nor were there indications that they were anything beyond mere accidental intruders.

The blood may be highly virulent in the absence of all other symptoms or phenomena. We know this virulence to exist for not less than thirty-five months in an experimentally infected case, and further investigations will probably reveal the fact that it is retained for a much longer period. We do not believe that in all of the cases of this character the blood remains permanently virulent as there are some indications that warrant the belief that after a long time its virulence becomes less and finally disappears. Our investigations, however, have not yet advanced far enough to permit of a definite statement in this regard.

Albuminuria is frequently seen in cases of "swamp-fever," both in the field and experiment cases. It is not a constant accompaniment of the disease; sometimes it will be in evidence in a given case, while a little later, it may have completely disappeared. At no time have we found the amounts of albumen, mentioned by European authors. In a few cases there was a sharp and well defined albumen reaction, but in the greater number, only traces were present. Only in one case were we able to find tube casts in the urine.

Polyuria is occasionally seen and especially towards the latter stages of the anemic field cases.

The chronic cases usually die from general exhaustion, supplemented by cardiac weakness, while in the more acute cases, the immediate cause of death is not explained by the lesions found after death.

In some of the latter types of cases, we found that death could be attributed to thrombosis of the pulmonary vessels, while in others no anatomic changes explained the exitus lethalis. Here we probably had to deal with a true intoxication and subsequent interference with the more essential parenchyma.

When we carefully analyze the clinical features presented by our cases. we will be struck by the regular presence of anemia in the field cases and its rather uncommon occurrence in the cases in which the disease was experimentally transmitted. The blood of field cases never failed to induce infection into the experimental horses and from them it could be passed into other horses again with almost unbroken regularity and often with fatal results and yet in no case were the symptoms of the original field case fully duplicated.

Were it not for the fact that this was regularly the case in all experiments involving six field cases from different sources of origin, we might be warranted in believing that the original infection had not been transmitted, but that some other virus had accidentally interfered with our work. The repetition of our observations, and the findings during the autopsy, however, would preclude such a conclusion. It may be suspected that in our experimental cases certain contributory causes are not in operation. Such cases are well fed, housed and not exposed to the wear and tear incidental to hard farm work, while in our field cases the opposite is not uncommonly the case. We will not deny the influence of the factors mentioned, but the fact that many of our experimental cases, in spite of the complete absence of anemia, terminate fatally, seems to indicate that the virus introduced is capable of producing fatal disease without any contributory cause cooperating in the process.

In an endeavor to explain this peculiar finding another theory may be advanced, namely, that the anemic cases, are the only ones which are diagnosed as "swamp-fever" and that perhaps they only constitute a certain fraction of all swamp-fever cases. The clinical observations made on our non-anemic experimental cases, convince us that, had they occurred under actual field conditions, they would either have escaped attention altogether or would not have been diagnosed as swamp-fever.

In just this type of cases, we would never suspect the disease, if we did not know that they were artificially infected, as the symptoms presented are so extremely indefinite as to most commonly preclude a clear cut diagnosis. We lean, therefore, more or less to the opinion that the anemia so commonly associated with the disease is by no means a constant occurrence and that we will have to reconcile ourselves to the idea of non-anemic swamp-fever cases, in other words that in only a certain number of the cases anemia is a feature. We have a similar instance in the case of carcinoma in man. There, anemic conditions under certain circumstances are considered sufficient to warrant the suspicion of cancer, in fact, cancer is frequently accompanied by anemia. Yet many cancer cases exist, continue and die without anemia being a feature.

Unfortunately, we have no reliable field data, covering this point, but we may mention the fact that often, when making inquiry regarding swamp-fever outbreaks, informers will tell us something like this: "Yes, we lost quite a few horses, but only a few died with swamp-fever, as the others that died were sick only a few days and it takes swamp-fever much longer to kill a horse."

We are in hopes to carry our experimental work into the field during the coming season and then this point will be more thoroughly looked into.

If the above opinion be correct, it seems that the diagnosis offers greater difficulties than was heretofore supposed. Most authors seem to regard the diagnosis of "swamp-fever" as something easily accomplished, and but little space is devoted to its discussion.

Köpke (8) mentions "Brust-seuche" (infectious pneumonia), febrile gastro-enteritis and pernicious anemia as of importance in the differential diagnosis, while Torrance (9) regards the dragging gait, the good appetite, accompanying loss of flesh, anemia and the peculiar thrilling pulse as diagnostic evidence. Peters (26) does not consider the diagnosis to be very difficult during the later stages of the disease. He considers the anemia and progressive emaciation, combined with the good appetite, as good grounds for a diagnosis. Hempel (49) moving along more rational lines experiments with a view of determining the existence of the disease by the complement fixation method, but his results appear to indicate that this method cannot be relied upon to become an aiding factor in the diagnosis. Hutyra and Marek (69) take into consideration influenza catarrhalis, anthrax, enzootic spinal paralysis, piro-plasmosis, Sclerostomiasis and simple anemia when dealing with the differential diagnosis of the disease. To Mack (50) the correct diagnosis of swamp-fever does not appear to be without its problems, at least, he speaks of the difficulty of differentiating this disease from other conditions accompanied by anemia. In this differential diagnosis, he attaches some importance to the relative increase of lymphocytes and the corresponding decrease in the polynuclear cells of the blood. He also lays stress on the value of eosinophilia as an evidence of helminthiasis. The acceleration of respiratory and cardiac activity after exercise is also looked upon by Mack as a valuable aid in the diagnosis. Mohler (52), on the other hand, states that the diagnosis is not difficult and he regards the symptoms, usually met with in swamp-fever cases as sufficiently characteristic to warrant a diagnosis. Kinsley (63), when making the diagnosis is guided by the presence of a high temperature, anemic pulse, anemic cardiac murmur, jugular pulse, petechiæ on or a muddy appearance of the conjunctiva, relaxation of the sphincters, enlargement of the sub-maxillary lymphnodes and general depression. To this he adds that locality and history must be given due credit and asserts that "blood inoculation is the only positive method of diagnosis in this disease." According to a Prussian source (55) "infectious anemia" may be suspected when there are observed: dullness, a bad state of nutrition, pale and pinkish white mucosæ, reduction in the erythrocyte contents of the blood, increase in the pulse frequency (especially marked after exercise). To those phenomena there may be added, fever, subcutaneous edema and albuminuria. In one of the cases studied by Todd and Wolbach (75), the animal when first examined appeared healthy, the blood count amounting to 6,500,000 erythrocytes, which in the course of three months rose to 8,500,000 and the authors add that, were it not for the distinct rises of temperature which followed in the horse which was inoculated with the blood from the case, it would be permissible to question whether it were ever infected with swamp-fever. The same authors record a blood examination in a horse four months after inoculation and which was down and unable to rise and yet the count revealed 10,640,000 red corpuscles and 29,500 leucocytes per cubic m. m., while the hemoglobin amounted to 115 per cent.

If "swamp-fever" under natural conditions only occurred in the form of the anemic disease, which we had occasion to describe in a former paragraph, the problem of diagnosis would become simplified to a remarkable extent. But even then a clear cut definite diagnosis, such as is possible in so many of our infectious diseases, would often be impossible if we had to depend on objective symptoms alone. Accepting the experimental evidence of the existance of a non-anemic form of the disease, and especially with reference to what may be called non-clinical infection carriers, we find that the task of correctly diagnosing the disease is not only highly difficult, but more frequently even absolutely impossible with the means and knowledge now at our command. In fact, for so far as our observations go, we have come to recognize in the problem of the diagnosis, the most difficult phase in our investigations. It is true that for purposes of experiment, we have recourse to the inoculation of a healthy horse, but this method of diagnosis can only find a very limited application in actual every day practice. The absence of an absolutely reliable method of diagnosis, aside of offering an enormous obstacle, also places a great part of field and experimental data in the doubtful column. Every so often we learn of a certain line of treatment, for example, which proved to be beneficial in "swamp-fever" or even "cured" cases of the disease, but before accepting those statements at their face value we may well question, what evidence is there of an absolutely correct diagnosis and if the diagnosis were correct by what method was the cure proven?

Under the existing difficulty of diagnosis, a greater part of the evidence on swamp-fever becomes worthless and under these conditions we have come to accept only such evidence as can be supported by actual inoculation tests.

In spite of unreliable objective symptoms, a diagnosis is however, often possible, especially in the anemic type of the disease. Aside of the ascertaining of the various symptoms mentioned above, an inquiry into the circumstances surrounding or preceding the case under observation, is imperative if we wish to be guided toward correct conclusions. An anemic fever case, with occasional albuminuria, edema, a swaying gait is in itself sufficient to arouse suspicion, but when this evidence is supplemented by a history of several, previous cases of the same nature and this all in a locality reported to be a swamp-fever center, it becomes quite safe to make a swamp-fever diagnosis. Such supplementary evidence, may and would also aid in arriving at a plausible conclusion in the face of indefinite non-anemic illness, marked by remittent or intermittent fever, even if an unimpeachable diagnosis cannot be obtained. The question of picking out from an infected herd, the non-clinical infection carriers, however, important, is as yet very difficult. Unless we resort to inoculation experiments, we could only offer one suggestion and that is to record the daily temperature for long consecutive periods. Such cases, the great majority of them at least, will sooner or later show their typic febrile exacerbations and this at least would be an indication of some practical value. However. it must not be forgotten that in some of the cases of this type, no fever reaction occurs and that if it does occur, that we are not in position to definitely attribute it to swamp-fever infection. Here possibly, the demonstration of albuminuria may help out, although this condition could very well occur in other infections.

After carefully considering our evidence in the light of our present knowledge, we must conclude, that with the exception of the diagnosis of the anemic cases, with a history of infection, we are not able to promptly recognize the disease. We maintain, therefore, that in the matter of diagnosis, investigators have as yet to solve, perhaps the principal problem of the disease.

Abderhalden and Frei (67) and Abderhalden and Buchal (74) report a series of experiments, which tend to show that the blood serum of horses infected with pernicious anemia exerts a marked inhibitory action upon the hemolysis induced by saponin. As the reaction was not studied in case of other febrile diseases, our judgment of the practical value of this reaction must as yet be suspended, but at any rate the findings of the authors mentioned should stimulate further investigation.

In view of the difficulty of correctly diagnosing "swamp-fever" in all its forms, the data on the prognosis must also be accepted with a considerable amount of caution and it seems probable that the information available principally pertains to the anemic cases. Of the sixteen cases observed by Köpke (8) nine terminated fatally and of those one colt died on the fourth day of sickness. In the cases running a favorable course, the temperature gradually receded to normal in from six to eight days, and Köpke states that they made a complete recovery. Torrance (9) says that the duration of the disease extends over two or three months, but that in some more aggravated forms, the animals die in from two to three weeks. Torrance considers the prognosis as being very unfavorable and places the mortality figure between 50 and 100 per cent. In the opinion of this author, a small part of the cases recover when treatment is begun early and when the erythrocyte destruction has not exceeded a certain limit. In the report of Brimhall, Wesbrook and Bracken (10) the unfavorable prognosis and the futility of medicinal treatment are dwelled upon. They estimate the mortality of the cases at 80 per cent. In Rutherford's (11) experience recoveries are very rare. He says that apparent recoveries are sometimes noted, but a sudden relapse is not uncommon in such cases. Jarmatz (14) places the mortality at about 10-15 per cent if suitable treatment is begun soon after recognition. Ostertag (35) states that recovery from the typical disease is exceptional and requires a long time. Hutyra and Marek (69) inform us that recovery seems to be a rare exception and that if it takes place at all, it may only be apparent. Mack (50) places the mortality figure as probably well above 90 per cent of the cases. In Mohler's (52) description of the disease, the mortality is rated at 75 per cent or even higher. He states that recovery takes place only when treatment is begun early or when the animal has a long convalscent period, but follows this up with the statement that the treatment of the disease "has so far been far from satisfactory." Kinsley (63) advises a guarded prognosis, although he gives the opinion that if the veterinary directions were followed the mortality would not be over 25 per cent.

It is, of course, impossible to construct mortality statistics from the cases, field and experimental, that came under observation of the writers, as in a number of cases the cause of death was open to question while in not a few instances, the animals, although infected, were not permitted to live long enough for the disease to run a natural course.

The following table gives a review of the fate of our cases:

	Field cases	Exp. cases	Remarks
Still alive	1	6	
Died or killed in moribund state	5	24	Among those there are five of which the cause of death is doubtful
Infected but killed in fair condition	....	13	
Cases resistant to infection	....	4	One of those was destroyed on account of bone fracture

In a disease in which the diagnosis is manifestly beset by so many difficulties, most data on prognosis can only be accepted with suspicion as to their accuracy. In the type of the disease, that is commonly diagnosed as "swamp-fever," we are safe in expecting an unfavorable termination, and in placing the mortality percentage as ranging between 90 and 100 per cent. Recoveries have often been reported but such reports mean but little if they are not substantiated by positive proof that the blood of such cases is no longer virulent. In a disease of infection and evidently transmissable, recovery should not only be meant to include restoration to health, but also that the case under consideration has ceased to be dangerous as a virus carrier.

There are indications, that recoveries may be more common among the non-anemic forms of the disease, but it also seems that recovery only takes place after a very long period, marked by indefinite febrile attacks and their accompaniments. As such cases, however, are actively infective during all this long time, it seems that a fatal termination after a brief illness, would be more economic than the actual recovery from the disease. It should not be overlooked, however, that a number of the non-anemic cases die early in this disease (See chart of No. 934), but we have not a sufficient amount of data at our disposal to warrant the naming of a definite death rate for this type of cases or for the disease as a whole.

As a general rule the presence of anemia, edema, emaciation, weakness, albuminuria and polyuria must be looked upon as bad omens. In the acute non-anemic cases, continued fever even if more or less remittent in type, or fever exacerbations following one another in rapid succession point toward a short duration and fatal termination. In those cases also we must look with apprehension upon a continued albuminuria and the presence of edematous swellings of the dependant parts of the body.

On the whole, the disease in all its forms will justify a rather unfavorable prognosis.

It is not a surprising feature that in so fatal and so damaging a disease as "swamp-fever" or as some authors prefer to call it "infectious anemia" numerous attempts have been made to save the animals affected by various methods of treatment. Köpke (8) directed his efforts so as to secure a proper diet and disinfection of the intestinal canal, while aside of this he aimed to reduce the fever and to sustain the heart functions. Torrance (9) tried the use of quinine, arsenic, iron, mercury, Crédé's silver, various potassium salts, without discovering any line of treatment which was uniformly successful. According to Rutherford (11), the long continued use of arsenic, as recommended in surra by Lingard in India, combined with mineral and vegetable tonics and a change to high, dry grounds has perhaps been more satisfactory than any treatment yet tried. In a later report by Torrance (12) mention is made of therapeutic experiments with salol and that recovery followed in one of the cases, while the other case was lost by accident. From a subsequent report (15) it would appear that the recovery mentioned was only an apparent one.

Jarmatz (14) obtained the best results with white arsenic in quantities of 15 grains per day, supplementing this treatment by a highly nutritious diet. He mentions claret as to be of service also.

Ries (27) uses the following treatment in his "infectious anemia" cases; viz., assimilable food, hygienic care and surroundings, stimulants, febrifuges, tonics, blood builders. When fever is present 15 grammes of quinine sulphate are given at one dose, while at each meal a bottle of claret is administered and a few liters of cold water are injected per rectum about three or four times per day. Against the albuminuria, which is a usual accompaniment, Ries uses a milk diet. In the morning ten liters of sweet cold milk, are given and immediately after some crushed or whole oats with a little bran. To this starchy ration the author adds, morning and evening, a spoonful of cooking salt and the same quantity of phosphorated oil (1:300). At evening the patient is watered, with water containing iron prepared by permitting water acidulated with 30-40 grammes of hydrochloric acid to act on rusty iron. When the disease reached the stage where the test tube revealed a clot which only was one-fifth of the total quantity, two patients, showing voluminous sub-ventral edema received morning and evening eight liters of physiologic salt solution until from 80-100 liters were thus given, but notwithstanding a slight improvement, after the first injections at least, death was not prevented.

Ostertag (85) relates an experiment with atoxyl as a therapeutic agent. The subcutaneous administration of doses of 10 and 15 c. c. of a ten per cent solution of atoxyl was followed by a marked improvement in the clinical appearance of two cases, although notwithstanding this apparent improvement, the hemoglobin percentage and red blood cell count showed a reduction.

Friedrich (44) reports that iron and arsenic preparations were given with unsatisfactory results. Apparently better results were obtained by the use of bicarbonate of potash, but Friedrich expresses the fear that the improvement obtained is only a temporary one, in view of the remittent character of the chronic form of the disease.

In a later publication Ries (47) mentions a trial with atoxyl and concludes that it is both harmless and useless.

His best results were obtained with infusion of salt solution.

A strenuous therapeutic activity is displayed by Acres (48) who used, either in combination or separate, liquor cresol, strychnine, potassium-chlorate, anti-febrine, ferric-sulphate and nux vomica. He also tried quinine sulphate, potassium iodide, resublimed iodine, arsenic, hydrochloric acid and "other drugs," but obtained the best results from the anti-febrine treatment. He qualifies this statement, however, by saying: "The animal, however, is generally subject to several relapses, which none of the drugs above mentioned seem to prevent." Acres winds up by trying antistreptococcic serum and states that his results were so encouraging that "it would be worth while giving this serum a thorough test."

Hempel (49) also experimented with atoxyl as a therapeutic agent. It was given in doses ranging from 0.5 G.-4 G., by gradual increase. Apparently the atoxyl treatment resulted in a marked improvement of the cases, although the blood of a horse thus treated was still infectious after it had received 26 G. in the course of about six weeks.

Hutyra and Marek (69) state that thus far no medicinal treatment of promise has been found, but make mention of the fact that certain arsenic preparations, at least in certain cases, seem to have a favorable influence.

Kinsley (68) gives a first place to absolute rest in the stable because "sunshine has a decided injurious effect upon the diseased animals." Cold baths and enemata to reduce the temperature in the acute type, while stimulants and the use of arsenic are relied upon for the rest. He states that this line of treatment continued from 4-6 weeks apparently completely destroys the causative agent of the disease, at least, the animals recover.

Mohler (66) seems to approve of the use of certain drugs but he regards the results treating the disease as far from satisfactory.

Van Es (68) thinks that in a therapeutic effort, iron and arsenic, perhaps are best indicated, but that even with them no marked results can be anticipated.

Francis and Marsteller (81) made some therapeutic experiments with quinine, trypan-blue, trypan-red and atoxyl. The results of the latter three drugs were either doubtful or negative, but the authors speak of some encouragement from the use of quinine. It may, however, be mentioned that the case in which quinine was used, was under observation only for a short period afterward, and that the virulence of its blood was not tested after the treatment.

Whitehouse (83) used trypan-blue, giving only one injection of three grains dissolved in 200 c. c. of sterile cold water or physiologic solution, and expresses the opinion that in one of his cases recovery was due to the trypan-blue treatment. The results of the treatment apparently were not verified by experimental evidence.

From the above it would seem that the present status of swamp-fever therapy is as yet deplorably inefficient, and that in the way of treatment, we have nothing that promises to be specifically useful. In the absence of such a treatment, we will have to confine ourselves to meeting the symptoms as they arise, if we consider it worth while to do anything at all. Antipyretic treatment, medicinal or otherwise may be employed during the febrile periods, while in the anemic cases the use of the arsenic and iron may be tried. At one time it appeared that we obtained good results by giving six grains of arsenic, mixed with one drachm of the carbonate of iron on the feed morning and evening, and continued for a month at a time, but as neither our diagnosis nor the results of our treatment were verified by means of inoculation experiments, this evidence will have to be rejected as insufficient. As long as the horse owners are bound to demand medicine, to be swallowed by their sick horses, the arsenic-iron combination can perhaps not readily be improved upon, at least, it will in many cases prevent the use of irrational or freak remedies.

Whatever treatment be undertaken, it should be supplemented by the use of proper food and water and by placing the patient in hygienic surroundings.

A beginning has been made with some therapeutic experiments, which we hope to continue as the proper material for it becomes available.

The first trials concerned a preparation, most widely known as trypan-blue and which had gained some reputation abroad as being of use in certain diseases of infection caused by protozoa. The firm of Meister Lucius und Brüning, Hoechst A. M., Germany, was so kind as to place a liberal quantity of trypan-blue at our disposal and the following experiments were tried with it.

Experimental horse No. 855, shortly after its initial fever was given an intravenous injection of three grammes trypan-blue in 250 c. c. physiologic salt solution and the injection repeated every other day until six injections in all were given. There was apparently no constitutional disturbances caused by the injections. The mucosa became of a dense, ashy blue color, after the first injection and this blue was still apparent some six weeks after the last injection. During the three and one-half months which the animal was permitted to live, there were no fever exacerbations, although on a few occasions the temperature ranged between 101° F., and 102° F. When 48 hours after the third trypan-blue injection the blood of this case was drawn it still proved to be virulent.

A subcutaneous injection, of 60 c. c. of this blood made after the last dose of typan-blue into experimental horse 873, caused this animal to become infected, showing the initial fever between the 10th and 21st days after inoculation. Immediately after the first febrile period and during part of the second one, this animal received seven intravenous injections of 3 grammes of trypan-blue in 250 c. c. of physiologic salt solution, and sustained the injections very well. The mucosa and the urine became quite blue but otherwise, there were no ill effects attributed to the drug. Up-to-date this animal's temperature has not been above 102.5° F., although the animal, while not anemic, looked unthrifty most of the time. When this horse's blood, however, was fed to experimental horse No. 903, it again produced positive infection.

While we hope to resume the experiments with trypanblue, it would appear from the above experiments that it cannot be relied upon to destroy swamp-fever virus in vivo.

The one experiment, systematically made with atoxyl, resulted similarly.

Again using experimental horse No. 873, the following subcutaneous injections with a 10 per cent solution of atoxyl in physiologic salt solution were made:

Date	Amount	Date	Amount
9-23-10	10 c. c.	10- 8-10	40 c. c.
9-24-10	10 c. c.	10- 9-10	40 c. c.
9-25-10	10 c. c.	10-10-10	50 c. c.
9-26-10	15 c. c.	10-11-10	40 c. c.
9-27-10	15 c. c.	10-12-10	40 c. c.
9-28-10	15 c. c.	10-13-10	30 c. c.
9-29-10	20 c. c.	10-14-10	30 c. c.
9-30-10	20 c. c.	10-15-10	25 c. c.
10- 1-10	20 c. c.	10-16-10	25 c. c.
10- 2-10	25 c. c.	10-17-10	20 c. c.
10- 3-10	25 c. c.	10-18-10	20 c. c.
10- 4-10	25 c. c.	10-19-10	15 c. c.
10- 5-10	30 c. c.	10-20-10	15 c. c.
10- 6-10	30 c. c.	10-21-10	10 c. c.
10- 7-10	30 c. c.	10-22-10	10 c. c.

After the tenth injection there was a slight attack of colic but otherwise nothing out of the ordinary was observed. During the injection period the animal lost flesh a little, but no evidence that the atoxyl had anything to do with it could be detected.

During the month of treatment this animal thus received 71 grammes of atoxyl and yet, when a week after the last dose, this animal's blood was drawn and injected into experimental horse No. 939, it produced disease after an incubation of ten days.

An as yet incomplete experiment with the use of quinine may be reported at this time, because the results thus far obtained already, indicate more or less what is to be expected when the returns will be complete.

Experimental horse No. 638 was given a series of intravenous injections of the hydrochloride of quinine, dissolved in physiologic salt solution, according to the following schedule:

6-22	1.0	500	
6-24	1.5	500	
6-26	1.5	500	
6-28	2.0	500	
6-30	2.0	650	
7- 2	2.5	650	
7- 4	3.0	650	
7- 6	3.5	650	
7- 8	4.0	650	
7-10	5.0	750	Slight tremors of Tensor fasciae latae.
7-12	7.0	900	Tremors well marked.
7-14	8.0	900	Tremors still more marked. An increase in pulse frequency of 5 beats per minute.
7-17	9.0	1000	Tremors involved more muscular regions of hind quarters.
7-19	10.0	1200	Tremors same as before. Increase in pulse rate 15 p. m.
7-21	11.0	1350	Subject restless; tremors extending to abdominal muscles. Pulse increase 20 p. m.
7-24	12.0	1500	Tremors general. Subject sways while moving. Pulse increase 30 p. m.
7-26	13.0	1750	Symptoms of 7-24-11 duplicate but more intense. Pulse increase 45 p. m.
7-28	14.0	2000	Muscular phenomena same as before.
7-31	15.0	2250	Marked muscular incoordination. Subject staggered. Pulse increase 65 p. m.

Between the tenth and fifteenth day after the last injection No. 638 sustained a typical fever exacerbation, while experimental horse No. 1068, which was injected with a quantity of serum drawn from No. 638, immediately before the quinine injection of 7-17-11 developed fever 24 days after inoculation.

Another experimental horse was injected with blood of No. 638 one week after the latter had received its last quinine injection, but as the usual incubation period has not yet terminated the evidence expected from this case cannot at this time be incorporated in our report.

The indications at this time thus, very strongly point that but little is to be expected from the use of medicines in the management of this disease. Like in the case of most diseases of infection, we will have to direct our attention more particularly to possible means of prevention.

Torrance (15) advised farmers through the agricultural press to avoid pasturing their horses and to water them only from wells and this advice has had a good effect in diminishing the number of cases and reducing the loss.

Carré and Vallée (19) formulated the following rules of prevention: 1. Isolate or still better destroy the sick animals, or at least, gather up and disinfect their liquid and solid ejecta. 2. Do not offer to drink, in infected regions, to healthy subjects anything but spring water or water which was previously boiled. 3. Never to place a horse coming from a suspected district, among healthy animals, without being certain beforehand that the urine does not contain albumen.

Ries (27) who, as will be remembered suspects "bots" of having an etiologic relationship to the disease, recommends thorough grooming and in particular the removal of the eggs of Gastrophilus and the early treatment with bisulphide of carbon on farms where the disease breaks out or where there is reason to suspect the presence of bots in the stomach.

In the opinion of Ostertag (35) it is primarily necessary in order to guard against the introduction of the disease, to exercise increased care in the purchase of new horses. Furthermore, new horses should be kept completely separated from the other occupants of a stable and all, opportunities of infection by means of contaminating the water or food supply should be carefully eliminated. He also insists on a water supply of unquestionable purity. Those preventative measures are recommended to be kept up for three months in view of the insiduous nature of the disease. When the disease appears in a stable, the affected animal is to be immediately segregated and the stable is to subjected to a thorough disinfection under veterinary supervision. Impervious stable floors are regarded as imperative in thorough disinfection. Manure from infected animals will be rendered innoxious by keeping it packed for one month in quantities of at least one cubic meter (1 meter equals 40 inches). Ostertag further recommends that the attention of horse owners be directed to this disease and that they be cautioned to be careful in making new purchases.

Béghin (22) recommends segregation of cases, disinfection of the stable and harness, as well as general hygienic measures.

The prophylaxis outlined by Hutyra and Marek (69) includes the prevention of the introduction of any horses, which are in a poor, anemic and weak condition, and of which the cardiac frequency increases markedly on slight provocation and which have albuminuria. In infected districts new purchases should be segregated for three months. For infected stables, isolation of the diseased horses and thorough stable disinfection are recommended.

Mohler (52) proposes segregation of healthy from sick horses, and thorough disinfection of premises and utensils.

Van Es (68) outlines a plan of prevention and mentions separation of healthy and diseased animals, and where this is not possible, the destruction of the diseased ones. The elimination of animals suspected of being "infection carriers" is also spoken of as well as thorough stable disinfection. On the suspicion that biting insects may be instrumental in the transmission, he also recommends that horses be protected against pests of this type. In conclusion, he recommends that "swamp-fever" be included among the quarantinable diseases.

As a transmissible disease, swamp-fever, must in the first place be dealt with like we deal with any other infectious disease. If we are to confine this disease to its present centers of infection, it will be necessary to exercise some supervision over the horse traffic in and from the infected districts. In fact, it would seem wise to suspend all movements of horses from an infected region, at least, for a certain time of the year, say from July to December, as evidently most of the actual transmissions take place during that time.

Animals showing such symptoms, as would warrant the suspicion of swamp-fever, certainly should not be moved from place to place, even after they have made apparent recovery, because of the now well established fact that such cases will remain actively infective for a long period.

Especially important is care on the part of farmers, having healthy stock, when introducing recently purchased horses into the stable. Owners of non-infected stables within the sections where the disease is prevalent, would do better to make their purchases outside of the district than within it, if they are in need of new horse stock.

Complete segregation of animals having the disease or suspected of having it must be carried out rigidly and the best way to do this is to leave the infected animals where they are and remove the horses, which are still in good health. Better still would it be to destroy the actual cases. In the great majority of instances such animals die anyway and the longer they are kept the more liable will they be to infect other stock.

When once the disease has made its appearance among a certain lot of horses and the apparent cases of the disease eliminated by destruction or otherwise, the possibility of infection still lurking about in the body of some horse which does not show symptoms becomes a serious problem and here we feel most acutely the imperfection of our knowledge of this disease. The results of our own investigations, as well as those of Vallée and Carré (17), Ostertag (35), and Francis and Marsteller (42) clearly indicate that such cases will have to be reckoned with. As yet we have no clear cut practical method by which such "infection carriers" or rather "infection distributors" may be detected. The best we can do under the circumstances is to keep track of the body temperature of all the horses in the stable, on the principle, that many of those so-called occult cases will from time to time show the typical transitory fever mentioned in another paragraph. In addition, we may examine the urine from time to time for the presence of albumen. Cases showing the characteristic temperature rise or albuminuria must be isolated on the ground of presenting symptoms, warranting the suspicion of swamp-fever.

Under all circumstances connected with real or suspected cases of the disease, thorough stable disinfection must be rigidly carried out. This must not be done in a perfunctory manner because much may depend on it.

In infected districts, damp, swampy or marshy pastures should either be avoided for horse stock or thoroughly drained. It is here where probably most of our infections occur, through the contamination of the foliage and water pools by the urine of swamp-fever cases and "infection carriers." It is also advisable to prevent horses from using the water found in ditches or pools of such pastures and instead the water supply should be derived from wells, protected against the contamination by surface drainage or seepage. The drinking troughs in which the water is offered should be well above the ground, so as to reduce the danger of contamination with body ejecta to a minimum. At the same time, the formation of small pools around troughs should be prevented, by providing a sufficient drain for the waste water. Undrained pastures which are unfit for horse stock may be safely used for other animals, for so far at least as "swamp-fever" is concerned. While probably most of our cases originate from pasture infection, there is plenty of evidence to show that stable infection also takes place and with that possibility in view, the stable should receive considerable attention in a hygienic way.

Remembering that we have absolute proof that the cause of the disease leaves the body of the infected animal by means of the urine, we can readily see how this substance may find its way into the well if it be sunk immediately under the stable. This is a practice prevalent on many farms and constitutes a source of great danger in this, as well as in many other diseases.

There is really but one condition under which a stable or barn-well can be permitted and that is when the stable is provided with a good concrete floor and when stable drainage is conveyed away from the building by an adequate arrangement.

We wish to call the attention of the farmers of fever infected districts, especially to these facts, as we feel certain that on many farms the disease can be brought to a standstill by paying attention to them. The common wooden stable floor, with its space full of inequity under it, explains the presence of many of our most stubborn diseases.

The constant presence of the specific virus in the blood and the well known part played by biting insects in the dissemination of other diseases seem to warrant us to include the protection of our horses against those pests and the eradication of them among the preventative measures.

It is but natural, that when dealing with an infectious disease, some attention should have been paid to the possibility of immunity as a factor including a promise of practical application. Owing to a rather recent solution of the etiology of the disease, nothing definite on swamp-fever has been thus far published.

Carré and Vallée (28) make mention of the fact that certain apparently recovered cases sustain large doses of virulent material without experiencing any grave disturbances, while they state that a beginning was made by them on some immunity experiments, which are to be made the subject of a future publication. Hempel (49), however, after experimenting in order to decide if horses which had apparently recovered from the disease had acquired an active immunity or not, found that such was not the case and that such animals seemed to be still susceptible to a second infection. Mohler (23) speaks of investigations being in progress with a view of producing a serum or vaccine for immunizing purposes. Melvin (70) concludes that natural immunity against swamp-fever does exist in some horses and that this immunity may be increased by repeated injections of virulent serum from which contaminations have been removed or by means of defibrinated blood.

Our own data on the question of immunity in "swamp-fever" are very scant. There are some indications that some of the experimental horses, which may have become mere non-clinical infection carriers or which perhaps have entirely recovered, are able to withstand large doses of virulent blood with impunity but our researches in that direction have scarcely advanced to the point, where it would be prudent to even think of conclusions. However, as a matter of illustration, the career of some of our cases may here be briefly summarized.

Experimental horse No. 637 was injected with a quantity of blood from field case No. 642 on August 11, 1908. As a result the animal sickened showing several marked febrile reactions between that and the latter part of November following. From then on to May 1909, the temperature remained practically normal. On March 20, April 13, May 14, May 30, and June 15, the animal received injections of virulent blood, from different animals, which were increased from 20 c. c. to 1100 c. c. After May the general run of temperature became a little higher but no sharp exacerbation took place until October 25, 1909, when the temperature rose to 103° F., and although no further injections were made for the time being, there were several distinct febrile attacks between that date and October 4, 1910, when a large quantity of virulent blood was injected. This was followed by an indefinite slight transitory reaction on October 12 and November 15, while a subsequent injection of a large quantity of virulent field blood on December 10, 1910, provoked sharp reactions on December 17, 1910, and February 2, 1911.

Encouraged by the fact that blood from No. 637 on June 15, 1909 failed to produce disease, the writers were induced to test its possible immunizing properties. This was done by the simultaneous injection of the blood of No. 637 and that of some other animal known to be virulent.

Acting on this plan experimental horse No. 729 was on July 13, 1909 injected with 50 c. c. of virulent blood from No. 638 and 500 c. c. of blood from No. 637. The horse was found to be dead on the following morning. Experimental horse No. 788 was used for a similar simultaneous injection on July 15, 1909, and succombed after a febrile period of eight days.

The experiment repeated on experimental horse No. 804 resulted fatally in five days, while experimental horse No. 811 lived only three days after injection.

Repeating the experiment in experimental horse No. 816 the results were again fatal in 25 days. In this case a marked anemia (2,500,000 red cells,) was observed two days before death.

From those observations it was evident that the combination of the blood of Nos. 637 and 638 had to be discarded as a base for immunity experiments.

It should, however, be observed that the experiment repeated on experimental horse No. 859 about one year late did not provoke any visible results. The horse experimente on had shown a high relative or perhaps absolute immunit to previous injections, which may in a measure account fo his surviving.

Experimental horse No. 638 was inoculated with a diluted virus, passed through a Pasteur Chamberland filte on 10-7-08, and showed several febrile periods, the curve showing their apices on the following dates: 10-18-08, 10-2 08, 12-10-08, 1-16-09, 3-4-09, 5-14-09, 10-18-09. Since th time the animal has shown only twice a very transito rise of temperature, at no time exceeding 102.5° F. B tween fever attacks and even after the last marked rise of 10-18-09, the animal has been a picture of health and vigor. Although No. 618 showed severe illness and great depression during several of its fever attacks, there never was the least evidence of anemia; in fact, the blood count always showed a higher figure than what is usually considered to be the normal standard for the horse.

However, in spite of what from a clinical standpoint may be considered a complete recovery, this animal's blood was still virulent on 5-20-10 to experimental horse No. 879, although the incubation period, longer than usual, (22 days) may perhaps be considered as an indication of attenuation.

This animal was injected with virulent blood according to the following table:

Date	Blood	C. C.
7-15-10	636	60
8-15-10	873	120
9-20-10	921	240
11- 1-10	919	550

The last injection was followed by a marked rise of temperature beginning 24 days after the injection.

The blood of No. 638 was still virulent on 5-3-11.

Among our experimental horses we found three animals which were naturally resistant to the infection.

Summarizing the results of our investigations, the writers feel warranted in submitting the following conclusions:

I. Swamp-fever is a disease of infection, transmissible by subcutaneous and intravenous injection and by ingestion through the alimentary canal.

II. The virus producing the disease is contained in the blood and urine of affected animals, but it is absent from the fæces.

III. The virus has thus far been demonstrated only in an ultra-microscopic form.

IV. The virus is resistant to the severe freezing weather of our more northern climates.

V. While not denying the possible transmission of the disease to healthy animals by means of insects and parasites, animals contract the disease naturally by the ingestion of food and water, contaminated by the urine of an infected horse.

VI. The disease is essentially a septicemia, anatomically marked by sub-serous and sub-endocardial hemorrhages in the more acute forms, by occasional involvement of the lymphnodes and spleen, by degenerative changes in the parenchyma of heart, liver, and kidneys, and probably also by certain alterations in the bone-marrow of the long bones of the limbs.

VII. The chief and most constant manifestations of the disease are fever and albuminuria. The former is remittent or intermittent, not uncommonly at more or less regular intervals, while the latter is transitory and frequently synchronous with the febrile exacerbations.

VIII. Many cases of swamp-fever terminate fatally without a marked reduction in the red blood cells, a fact denying the popular conception of "swamp-fever" being primarily an anemia.

IX. The blood of an animal may remain virulent for as long as thirty-five months after the initial infection, without the infected horse manifesting any clinical evidence of the fact.

X. Such non-clinical infection carriers probably play an important part in the establishment of more or less permanent centers of infection.

XI. Both trypan-blue and atoxyl are worthless in the treatment of the disease.

XII. In the light of our present knowledge we have to depend upon such prophylactic measures as the destruction of diseased animals, segregation of suspects, care in introducing new horses into the stable, the safe-guarding of food and water supply from urine contamination, pasture drainage and stable disinfection.

REFERENCES AND BIBLIOGRAPHY.

1. **Zschokke.** Progressive Perniziöse Anæmie der Pferde. Schweizer Archiv für Thierheilkunde. Band 25, s. 11 und 17. Zürich 1883.
2. **Fröhner.** Ueber Perniciöse Anämie beim Pferde. Archiv für wissenschaftliche und praktische Thierheilkunde. Band XII, s. 383. Berlin 1886.
3. **Ostertag.** Zur Casuistik der perniciösen Anämie beim Pferde. Monatshefte für praktische Thierheilkunde. Band I, s. 127. Stuttgart 1890.
4. **Muir.** On the changes in the bone-marrow in pernicous anemia. The journal of Pathology and Bacteriology. Vol. II, p. 354. Edinburg and London 1894.
5. **Perles.** Beobachtungen über perniciöse Anæmie. (Referat). Centralblatt f. Bakteriologie und Parasitenkunde. Band XV, s. 23. 1894.
6. **Watson.** Equine Relapsing Fever. American Veterinary Review. Vol. XX, p. 196. New York 1896.
7. **Taylor.** A case of malarial fever. The Veterinary Journal. Vol. 49, p. 1. London 1899.
8. **Köpke.** Fieberhafte seuchenartig auftretende Anämie der Pferde. Zeitschrift für Veterinärkunde. Band 13, s. 356. Berlin 1901.
9. **Torrance.** Malarial fever in horses in Manitoba. Proceedings of the American Veterinary Medical Association, 1902, p. 282. St. Paul.
10. **Brimhall, Wesbrook and Bracken.** Swamp-fever in horses. Reports of the Veterinary Department of the Minnesota State Board of Health. St. Paul 1903.
11. **Rutherford.** Swamp-fever. Report of the Minister of Agriculture for the Dominion of Canada for the year ended October 31, 1902, p. 85. Ottawa 1903.
12. **Torrance.** Report on "swamp-fever" in horses. Report of the Minister of Agriculture for the Dominion of Canada for the year ended October 31, 1902, p. 135. Ottawa 1903.
13. **Zypkin.** Zur Pathogenese der Bluterkrankungen. Virchov's Archiv. Band 174 (supplement) s. 1103. Berlin 1903.
14. **Jarmatz.** Anämie der Pferde. Zeitschrift für Veterinärkunde. Band 16, s. 68. Berlin 1904.
15. **Torrance.** Report on swamp-fever in the horse. Report on Health of Animals. 1903. Department of Agriculture of Canada. Ottawa 1904.
16. **Vallée et Carré.** Sur la nature infectieuse de l'anémie du cheval. Comptes rendus de l'académie des Sciences. Tome 139, p. 331. Paris 1904.

17. **Vallée et Carré.** Sur l'anémie infectieuse du chéval. Comptes rendus de l'académie des Sciences. Tome 139, p. 1239. Paris 1904.
18. **Beebe.** Swamp-fever. Second Annual Report of the Minnesota State Live Stock Sanitary Board, p. 49. St. Paul 1905.
19. **Carré et Vallée.** Rapport sur l'anémie infectieuse du cheval. Bulletin mensuel de l'Office de renseignements Agricoles. 1905. p. 1075. Paris 1905.
20. **Gulland and Goodhall.** Pernicious anemia. A histologic study of seventeen cases. The Journal of Pathology and Bacteriology. Vol. X, p. 125. Edinburg and London 1905.
21. **Torrance.** Report on the Pathology of Swamp-fever in Horses. Report on Health of Animals for 1904. Department of Agriculture of Canada, p. 112. Ottawa 1905.
22. **Béghin.** Enzootie d'anémie pernicieuse progressive chez les chevaux. Annales de Médecine Vétérinaire. 1906, p. 692.
23. **Carré et Vallée.** Recherches cliniques et experimentales sur l'anémie pernicieuse du cheval (Typho-anémie infectieuse) Revue générale de médecine vétérinaire. Tome VIII, p. 593 et Tome IX, p. 113. Paris 1906.
24. **Glage.** Beiträge zur Kenntniss der Pallisadenwurmkrankheiten der Füllen und der Pferde. Zeitschrift für Infektionkrankheiten, parasitäre Krankheiten und Hygiene der Haustiere. Band I, s. 341. Berlin 1906.
25. **Meier.** Beiträge zur vergleichende Blutpathologie. Zeitschift für Tiermedizin. Band 10, s. 7. Jena 1096.
26. **Peters.** Malarial Fever in Horses. Nebraska Agricultural Experiment Station. Press Bulletin No. 22. Lincoln 1906.
27. **Ries.** Sur la pathogénie et le traitement de l'anémie pernicieuse et infectieuse du cheval. Recueil de Médecine Vétérinaire. Tome. 83, p. 677. Paris 1906.
28. **Torrance.** Report on Swamp-fever investigations. Report of the Veterinary Director General 1905, p. 125. Ottawa 1906.
29. **Trincas.** Una ´forma d'anemia dei cani data un virus filtrible attraverso il Berkefeld W. Boll. Societa Cultori Scienze Mediche e Naturali Cagliari. IV. 1906.
30. **Hochstein.** Infektiöse Anämie. Wochenschrift für Tierheilkunde und Viehzucht 1907, s. 145.
31. **Ballah.** Report on "swamp-fever." Annual Report of the Department of Agriculture of the Province of Saskatchewan 1907, p. 223. Regina 1908.
32. **Brickman.** Beitrag zum Studium der perniziösen Anämie. Malaria des Pferdes. (Refeat) Deutsche Tierärztliche Wochenschrift. Band 15, s. 724. Hannover 1907.

33. **Charlton.** Swamp-fever. Annual Report of the Department of Agriculture of the Province of Saskatchewan 1906, p. 146. Regina 1907.
34. **Charon.** Note sur un cas de typho-anémie infectieuse au 6ç cuirassiers à Sainte-Menehould. Recueil de Médecine Vétérinaire. Tome 84, p. 531. Paris 1907.
35. **Ostertag.** Untersuchungen über das Auftreten und die Bekämpfung der infektiösen Anämie des Pferdes. Zeitschrift für Infektions krankheiten, parasitäre Krankheiten and Hygiene der Haustiere. Band III, s. 1. Berlin 1907.
36. **Vallée et al.** Sur la typho-anémie infectieuse. Recueil de Médecine Vétérinaire. Tome. 84, p. 526. Paris 1907.
37. **Van Es.** Seventeenth Annual Report of the North Dakota Agricultural Experiment Station, p. 48. Fargo 1907.
38. **Weinberg.** Du rôle des helminthes, des larves d'helminthes et des larves d'insectes dans la transmission des microbes pathogènes. Annales de l'Institut Pasteur. Tome 21, p. 417 et 533. Paris 1907.
39. **Weinberg.** Action de l'extrait de Sclérostomes sur le sang de cheval. Annales de l'Institut Pasteur. Tome 21, p. 798. Paris 1907.
40. **M'Fadyean.** The ultravisible viruses. Journal of Comparative Pathology and Therapeutics. Vol. XXI, p. 235. London 1908.
41. **Carnegie Dickson.** The bone-marrow. London 1908.
42. **Francis and Marsteller.** Infectious anemia of the horse. Texas Agricultural Experiment Station. Bulletin No. 119. Austin 1908.
43. **Friedberger und Fröhner.** Lehrbuch der speziellen Pathologie und Therapie der Haustiere. Band II, s. 105. Stuttgart 1908.
44. **Friedrich.** Die perniciöse Anämie der Pferde. Berliner Tierärtztliche Wochenschrift 1908, s. 469.
45. **Lignières.** A propos de la typho-anémie et des pasteurelloses. Recueil de la Médecine Vétérinaire. Tome 85, p. 187. Paris 1908.
46. **Mohler.** Three diseases of Animals, which have recently assumed importance to the State Sanitarian. American Veterinary Review, Vol. XXXIV, p. 198. New York 1908.
47. **Ries.** Sur la pathogénie et le traitement de l'anémie pernicieuse et infectieuse du cheval. Recueil de Médecine Vétérinaire. Tome 85, p. 11. Paris 1908.
48. **Acres.** Infectious Anemia or swamp-fever. American Veterinary Review. Vol. XXXIV, p. 525. New York 1909.
49. **Hempel.** Beiträge zur Kenntniss der ansteckenden Anämie der Pferde. Zeitschrift für Infektionskrankheiten, parasitäre Krankheiten und Hygiene der Haustiere. Band 5, s. 381. Berlin 1909.

50. **Mack.** Equine anemia. Bulletin No. 68. Nevada Agricultural Experiment Station. Reno 1909.
51. **Mack.** A study of a serious anemic disease among horses. American Veterinary Review. Vol. XXXVI, p. 222. New York 1909.
52. **Mohler.** Infectious anemia or swamp-fever of horses. Circular No. 138. B. A. I., United States Department of Agriculture. Washington 1909.
53. **Mohler.** Swamp-fever in Horses. Twenty-fourth Annual Report of The Bureau of Animal Industry, p. 33. Washington 1909.
54. **Torrance.** Report on swamp-fever investigation. Report of the Veterinary Director General and Live Stock Commissioner 1906-1908, p. 71. Ottawa 1909.
55. Veröffentlichungen u. d. Jahres-Veterinär. Berichten der beambten Tierärtze Preussens. 1906. Theil II, s. 26. Berlin 1909.
56. **Whitehouse.** Notes on Swamp-fever or Infectious Anemia of Horses. The Ranchman's Reminder. Vol. VI, p. 3. Laramie 1909.
57. **Flower.** Report of the Louisiana State Live Stock Sanitary Board. Proceedings of the 13th Annual Meeting of the Interstate Association of Live Stock Sanitary Boards, p. 162. Chicago 1909.
58. **Darling.** Correspondence. American Veterinary Review. Vol. XXXVII, p. 375. New York 1910.
59. **Dietrich.** Untersuchungen über die Wirkung des Atoxyls bei Pferd und Hund. Deutsche Tieräztliche Wochenschrift, 1910, s. 81. Hannover.
60. **Braun.** Bösartige Anämie bei Pferden. Münchener Tierärztliche Wochenschrift. 1910, s. 230.
61. **Halverson.** Pernicious anemia. American Journal of Veterinary Medicine. Vol. V, p. 181.
62. **Hoefer.** Ueber ein unbekanntes Protozoon im menschlichen Blute bei einem Falle von Anämie. Centralblatt für Bakterioligie, Parasitenkunde und Infektionskrankheiten. Band 55, s. 19. Jena 1910.
63. **Kinsley.** Equine infectious anæmia. Proceedings of the American Veterinary Medical Association 1910, p. 118. Philadelphia.
64. **McGilvray.** Rarer forms of fever in Horses. Proceedings of the Veterinary Association of Manitoba 1910, p. 23. Winnipeg.
65. **Mack.** A fatal anæmic disease among horses. Proceedings of the American Veterinary Medical Association 1910. Philadelphia.
66. **Mohler.** Infectious anæmia. 25th Annual Report of the Bureau of Animal Industry, for the year 1908, p. 225. Washington 1910.
67. **Abderhalden und Frei.** Ueber das Verhalten des Blutes (Plasma

resp. Serum und rote Blutkörperchen) von an perniziöser Anämie erkrankten Pferden gegen Saponin. Archiv für wissenschaftliche und praktische Tierheilkunde. Band 36, p. 423. Berlin 1910.

68. **Van Es.** Swamp-fever. Dakota Farmer. Vol. 30, Nos. 18 and 19. Aberdeen 1910.

69. **Hutyra und Marek.** Spezielle Pathologie und Therapie der Haustiere. Band I, p. 849. Jena 1910.

70. **Melvin.** Swamp-fever of Horses. Report of the Chief of the Bureau of Animal Industry for 1910, p. 63. United States Department of Agriculture, Washington 1910.

71. **Thatcher.** Twentieth Annual Report of the State Agricultural Experiment Station of Washington, p. 13. Pullman 1910.

72. **Kinsley.** Infectious equine anemia. Report of the Fourteenth Annual Meeting of the United States Live Stock Sanitary Associations, p. 143. Chicago 1910 and American Journal of Veterinary Medicine. Vol. VI, p. 378. Chicago 1911.

73. **Mack.** Equine anemia investigations in Nevada. Report of the Fourteenth Annual Meeting of the United States Live Stock Sanitary Association, p. 137. Chicago 1910.

74. **Abderhalden und Buchal.** Weiterer Beitrag zur Feststellung der perniziösen Anämie der Pferde. Archives für wissenschaftliche und praktische Tierheilkunde. Band 37, s. 309. Berlin 1911.

75. **Todd and Wolbach.** The swamp-fever of horses. The Journal of Medical Research. Vo. 24, p. 213. Boston 1911.

76. **Melvin.** Infectious anemia of Horses. Twenty-sixth Annual Report of the Bureau of Animal Industry, (1909), p. 46. Washington 1911.

77. Swamp-fever. American Journal of Veterinary Medicine. Vol. VI, p. 428. Chicago 1911.

78. **Kaupp.** A typical blood picture of pernicious anemia. American Veterinary Review. Vol. XXXVIII, p. 675. New York 1911.

79. **Halloran.** Infectious Anemia. American Veterinary Review. Vol. XXXVIII, p. 671. New York 1911.

80. **Van Es.** Twenty-first Annual Report of the North Dakota Agricultural Experiment Station, p. 55. Fargo 1911.

81. **Francis and Marsteller.** Some recent experiments on infectious anæmia of the horse. American Veterinary Review. Vol. XXXIX, p. 132. New York 1911.

82. **Norton.** A practitioner's view of swamp-fever. American Journal of Veterinary Medicine. Vol. VI, p. 672. Chicago 1911.

83. **Whitehouse.** Trypan-blue in Infectious Anemia. American Journal of Veterinary Medicine. Vol. VI, p. 636. Chicago 1911.

EXPLANATION AND KEY TO PLATES IV, V, AND VI.

Plates IV, V, and VI indicate the various transmissions swamp-fever infection in the course of the research work done at the Veterinary Department of the North Dakota Agricultural College. The black figures indicate cases in which infection was positively transmitted, the white ones, the cases in which transmission failed and the pinto horses, in which results of infection were of a doubtful nature.

No. 562. A field case from the vicinity of Harwood, N. D.

No. 577. Experimental horse infected by means of intravenous injection of 8 c. c. of blood from No. 562.

No. 635. Experimental horse infected by means of a subcutaneous injection of 100 c. c. of blood from No. 640.

No. 636. Experimental horse infected by means of subcutaneous injection of 100 c. c. of blood from No. 635. Is still alive 35 months after injection.

No. 637. An experimental horse infected by means of a subcutaneous injection of 100 c. c. of blood from No. 642.

No. 638. An experimental horse infected by means of an intravenous injection of a filtered mixture of 100 c. c. of serum of No. 639 and 700 c. c. of physiologic salt solution.

No. 639. An experimental horse infected by means of a subcutaneous injection of 100 c. c. of blood from No. 637.

No. 640. A field case from the vicinity of Christine, N. D.

No. 642. A field case from the vicinity of Fargo, N. D.

No. 723. An experimental horse infected by means of an intravenous injection of a filtered mixture containing 100 c. c. of serum of No. 638, and 700 c. c. of physiologic salt solution.

No. 727. An experimental horse resisting infection with 500 c. c. of blood from No. 638 given subcutaneously.

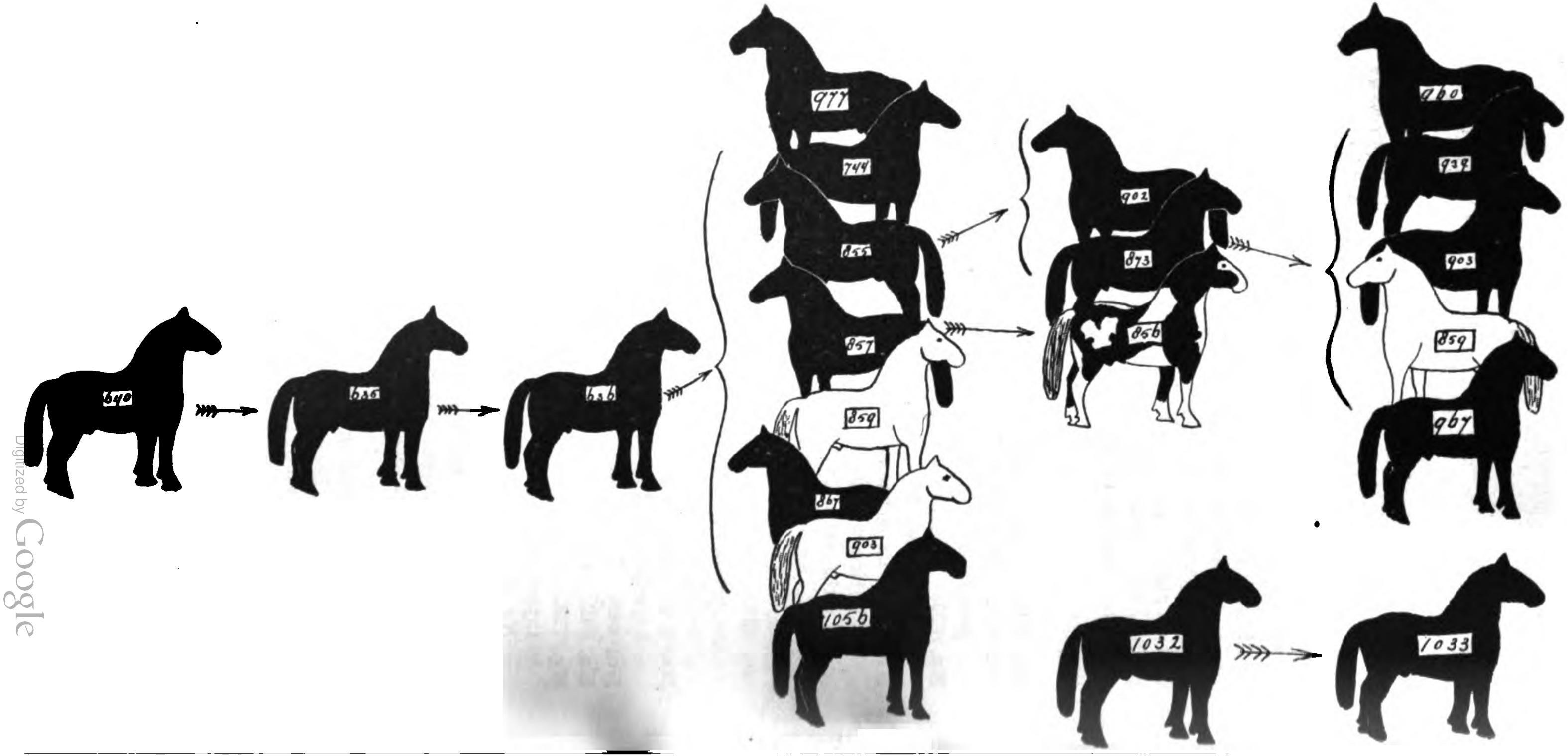
No. 729. An experimental horse, suddenly dying after an injection of 50 c. c. of blood from No. 638 and 500 c. c. of blood from No. 637.

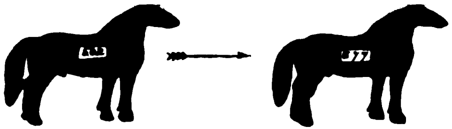
No. 743. An experimental horse, infected by means of a subcutaneous injection of 50 c. c. of blood of No. 638 and after having resisted a similar injection of 130 c. c. of blood from No. 637.

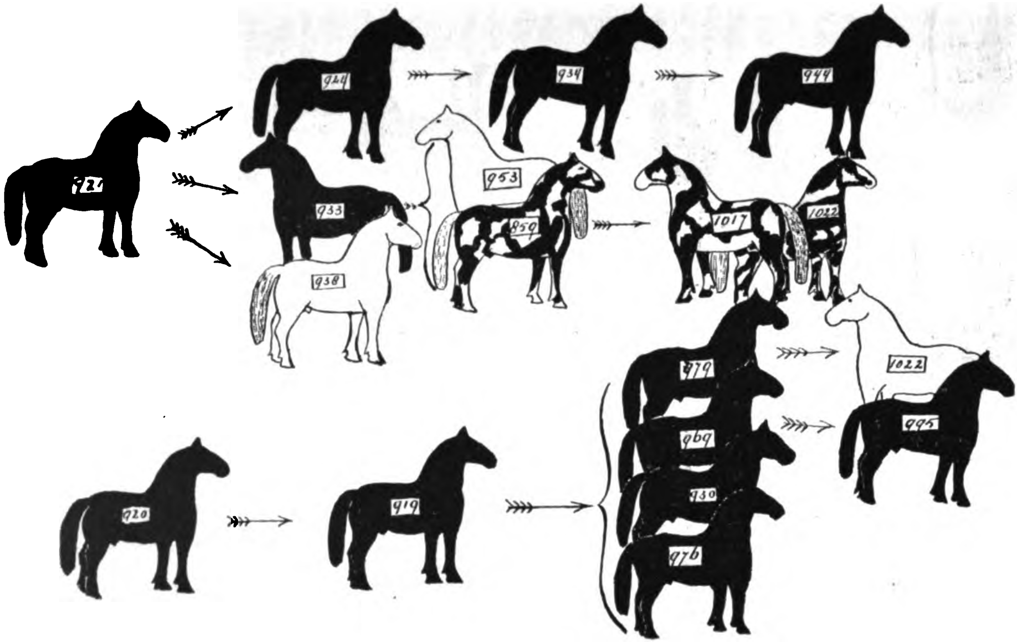
No. 744. An experimental horse, infected by means of a subcutaneous injection of 50 c. c. of blood serum from No. 636.

No. 788. An experimental horse, suddenly dying after an injection of 50 c. c. of blood serum from No. 638 and 500 c. c. of blood from No. 637.

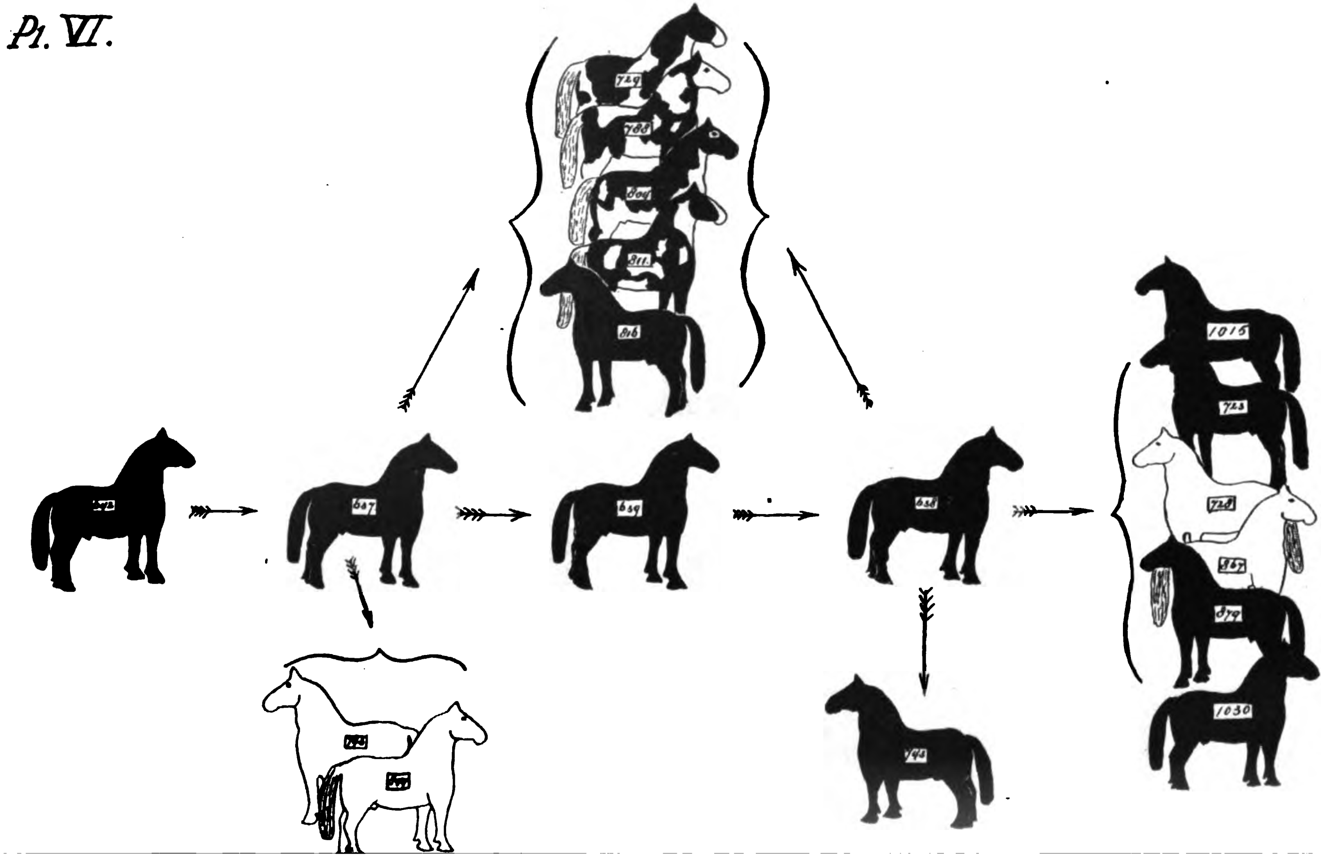
Pl. IV


640
656
636
977
744
855
857
859
867
903
1056
902
873
856
960
939
903
859
967
1032
1033


877



Pl. VI.



No. 804. An experimental horse dying six days after an injection of 50 c. c. of blood from No. 638 and 500 c. c. of blood from No. 637.

No. 811. An experimental horse dying three days after an injection of 50 c. c. of blood from No. 638 and 500 c. c. of blood from No. 637.

No. 816. An experimental horse infected by means of an injection with 50 c. c. blood from No. 638 and 500 c. c. of blood from No. 637.

No. 855. Experimental horse infected by means of a subcutaneous injection of 60 c. c. blood serum from No. 636, after having failed to react upon an injection of 100 c. c. of urine from the same source.

No. 856. An experimental horse, giving a doubtful reaction upon a subcutaneous injection of 60 c. c. of blood from No. 857.

No. 857. Experimental horse, infected by means of a subcutaneous injection of 60 c. c. of blood serum from No. 636, after having failed to react upon an injection of 100 c. c. filtered extract of fæces from the same source.

No. 859. Experimental horse, which has failed to react upon a subcutaneous injection of 60 c. c. of blood taken from No. 636, upon a subcutaneous injection of 60 c. c. taken from No. 873, upon a subcutaneous injection of blood taken from No. 637, upon a subcutaneous injection of 60 c. c. of serum from No. 638, and 60 c. c. of serum from No. 637, and upon an intravenous injection of 600 c. c. of blood from No. 919, but which showed an atypic reaction when injected with blood from No. 933.

No. 867. Experimental horse, infected by means of a subcutaneous injection of blood from No. 636, after having failed to react upon a similar injection with the blood of No. 638.

No. 873. An experimental horse, infected by means of a subcutaneous injection of 60 c. c. of blood from No. 855.

No. 879. An experimental horse, infected by means of a subcutaneous injection of 60 c. c. of blood from No. 638.

No. 902. An experimental horse, infected by means of a subcutaneous injection of 120 c. c. of blood from No. 855.

No. 903. Experimental horse infected by a daily dose of 50 c. c. of blood from No. 873, given by the mouth in capsules for ten days. Previous to this, this animal resisted a similar treatment with daily doses of 25 c. c. of blood from No. 636.

No. 919. An experimental horse infected by means of a subcutaneous injection of 120 c. c. of blood from No. 920.

No. 920. A field case from the vicinity of Kelso, N. D.

No. 921. A field case from the vicinity of Shelly, Minn.

No. 924. An experimental horse infected by means of a subcutaneous injection of 120 c. c. of blood of No. 921.

No. 930. An experimental horse infected by means of a subcutaneous injection of 120 c. c. of blood taken from No. 919.

No. 933. An experimental horse infected by means of a subcutaneous injection with 240 c. c. of urine from No. 921.

No. 934. An experimental horse infected by means of giving 2000 c. c. of urine from No. 924 by the mouth.

No. 938. An experimental horse, which failed to react upon a subcutaneous injection with 60 c. c. of blood serum from No. 921.

No. 939. An experimental horse infected by means of a subcutaneous injection of 240 c. c. of blood from No. 873.

No. 944. An experimental horse, infected by means of a subcutaneous injection with 200 c. c. of blood from No. 934.

No. 953. Experimental horse, which resisted an injection [illegible] 250 c. c. of blood taken from No. 933.

No. 960. Experimental horse infected by means of a subcutaneous injection of 240 c. c. of blood taken from No. 873.

No. 967. Experimental horse infected by means of a subcutaneous injection of blood from No. 873.

No. 969. Experimental horse infected by means of a subcutaneous injection of blood from No. 919.

No. 976. Experimental horse infected by means of a subcutaneous injection of blood from No. 919.

No. 977. Experimental horse infected by means of a subcutaneous injection of blood from No. 636.

No. 979. Experimental horse infected by means of a subcutaneous injection of blood from No. 919.

No. 995. Experimental horse infected by means of a subcutaneous injection of blood from No. 976.

No. 1015. Experimental horse infected by means of blood from No. 638.

No. 1017. Experimental horse showing a doubtful reaction after an injection with blood of No. 859.

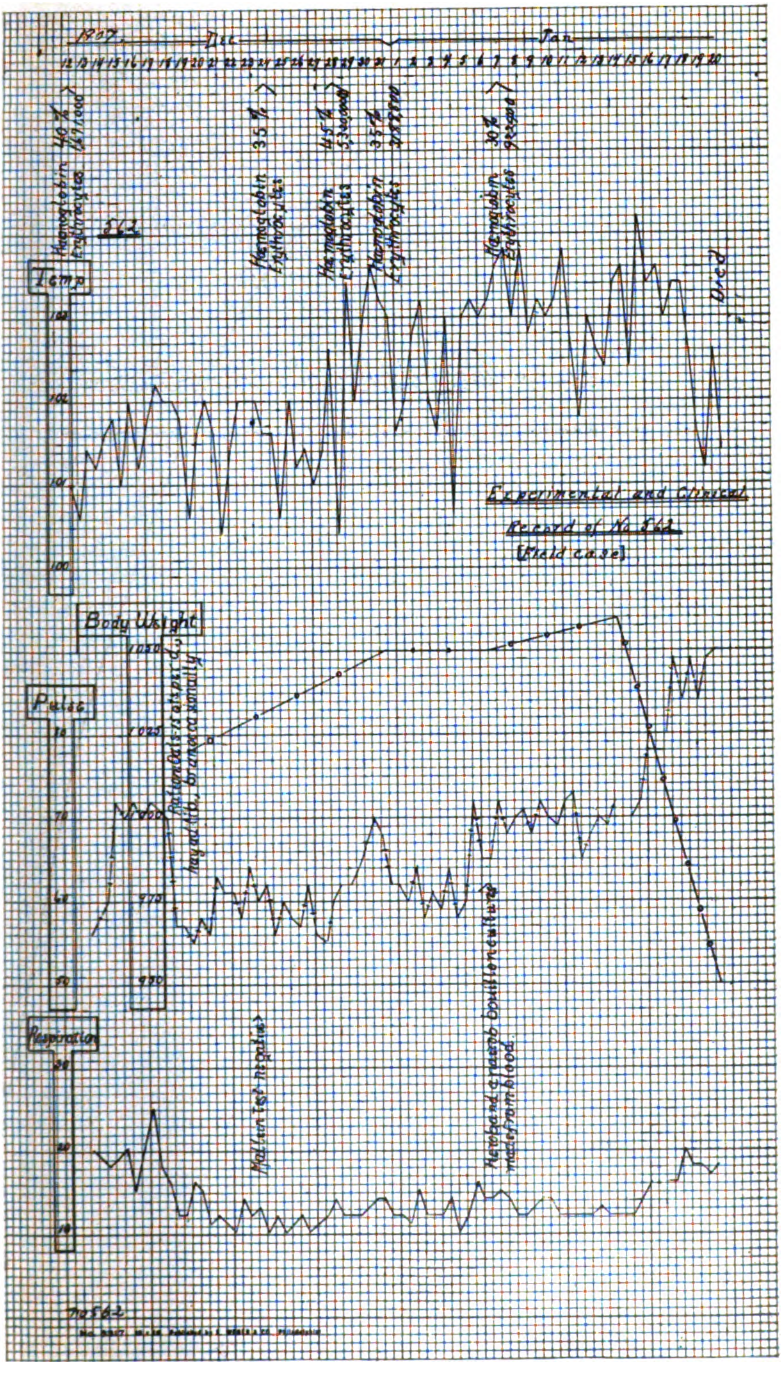
No. 1022. Experimental horse which failed to become infected by the blood of No. 979, but which showed a doubtful reaction after being injected with blood of No. 859.

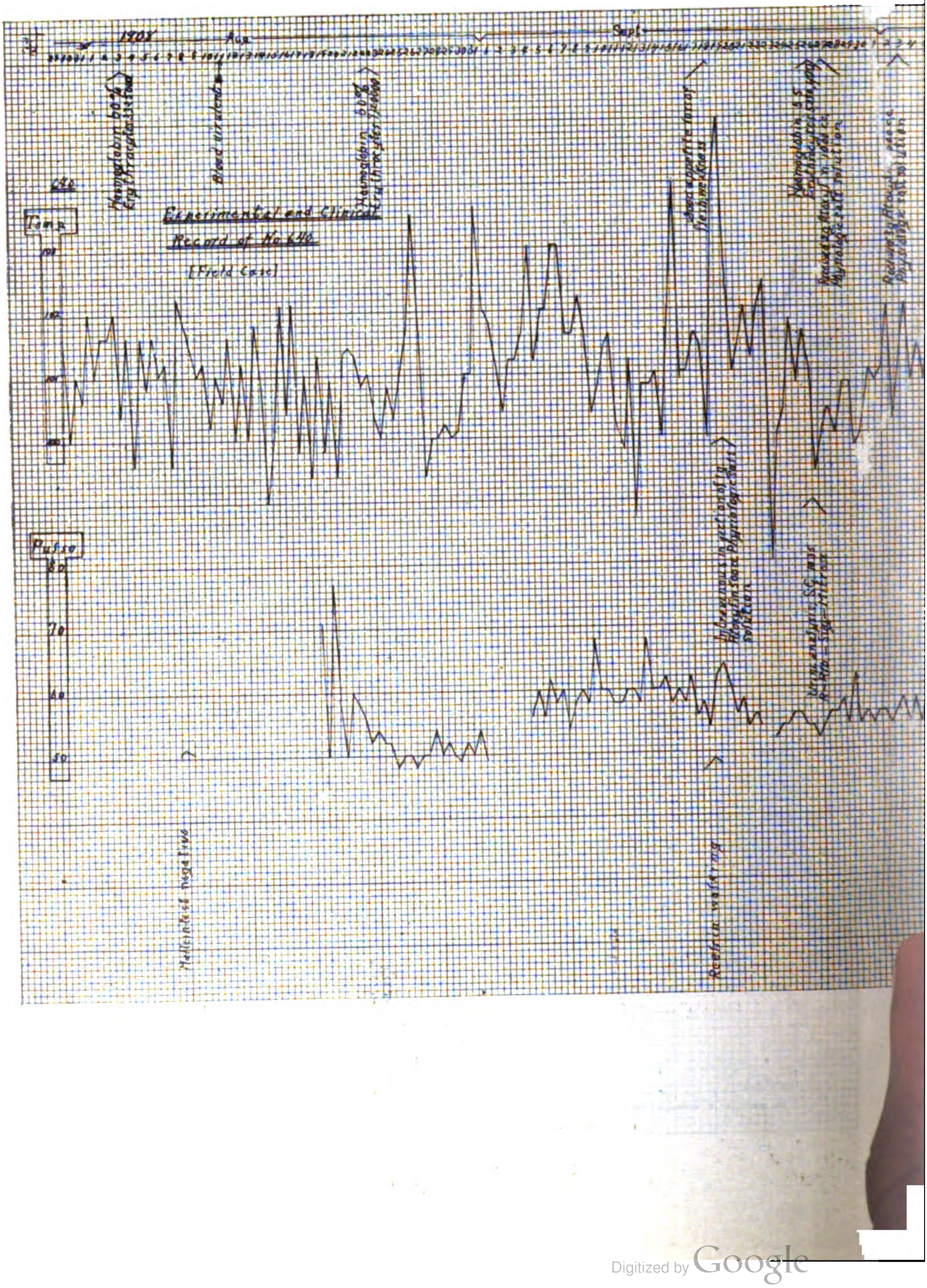
No. 1030. Experimental horse infected by means of blood from No. 638.

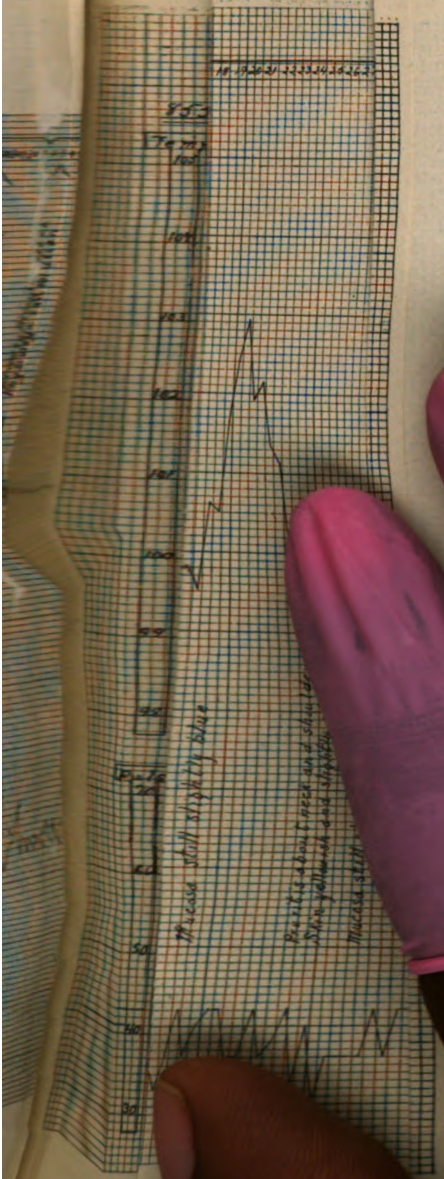
No. 1032. A chronic field case obtained from the vicinity of Neche, N. D.

No. 1033. An experimental horse infected by means of the blood of No. 1032.

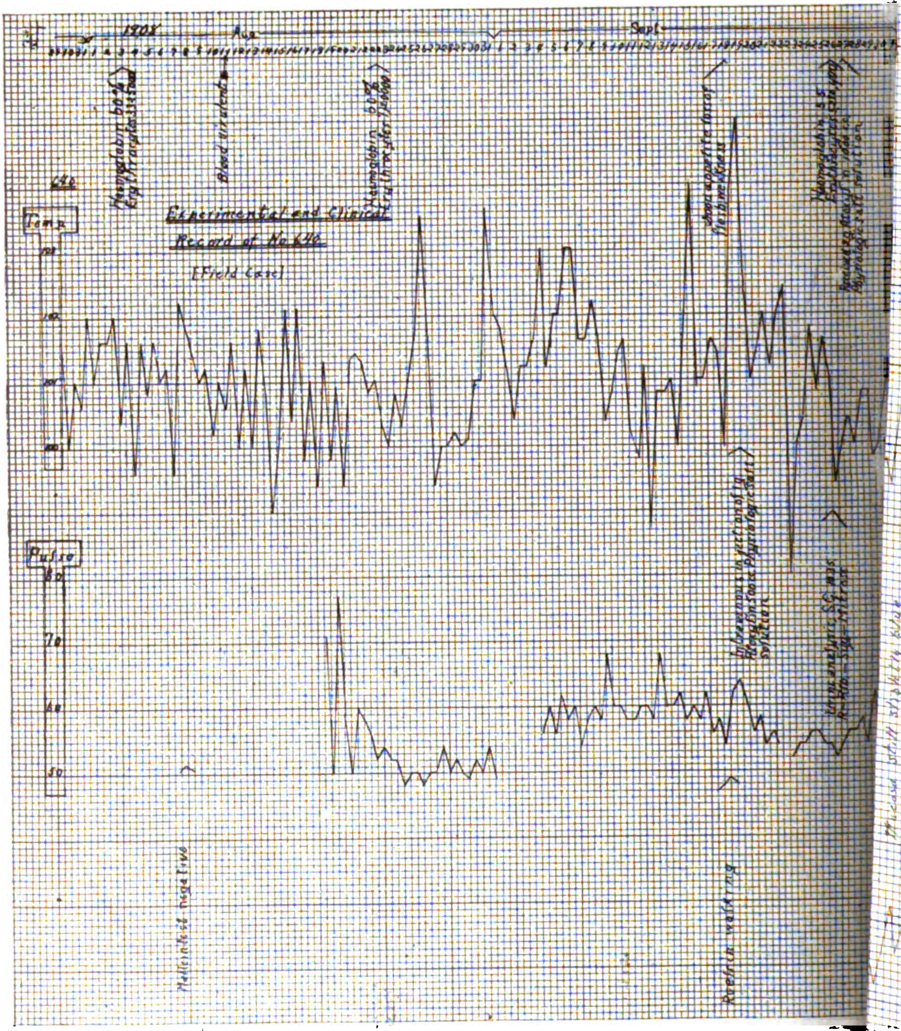
No. 1056. An experimental horse infected by means of the blood of No. 636.


1907.
Dec
Jan
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Haemoglobin 40%
Erythrocytes 5,291,000
562
Haemoglobin 35%
Erythrocytes
Haemoglobin 45%
Erythrocytes 5,300,000
Haemoglobin 35%
Erythrocytes
Haemoglobin 30%
Erythrocytes
Died
Temp
103
102
101
100
Experimental and Clinical Record of No. 562
[Field case]
Body Weight
1050
1025
1000
975
950
Put on oats 15 at 5 per d., hay ad lib., bran once daily
Pulse
80
70
60
50
Mallein test negative
Aerob and anaerob bouillon culture made from blood
Respiration
30
20
10
No 562

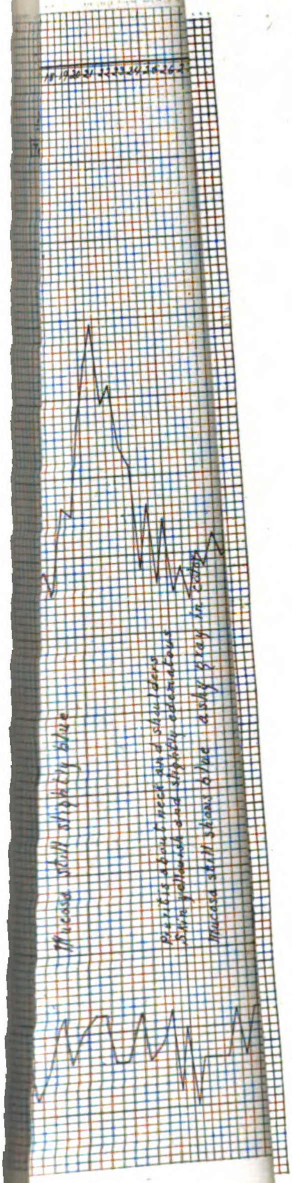

1908
Aug
Sept
646
Experimental and Clinical
Record of No. 646
[Field Case]
Temp.
103
102
101
100
Pulse
80
70
60
50
Haemoglobin 60%
Erythrocytes 3,375,000
Blood extracted
Haemoglobin 60%
Erythrocytes 3,456,000
Poor appetite, torpor
Distemper, Kraus
Haemoglobin 55
Erythrocytes 3,200,000
Recovering moist. in 100 cc
Physiological salt solution
Recovered strong, pace
Physiological salt solution
Intravenous injection of 19
Atoxyl in 500cc Physiological salt
solution
Urine analysis S.G. 1005
R. Alb. Sug. - Indican
Mallein test negative
Reefed in walking

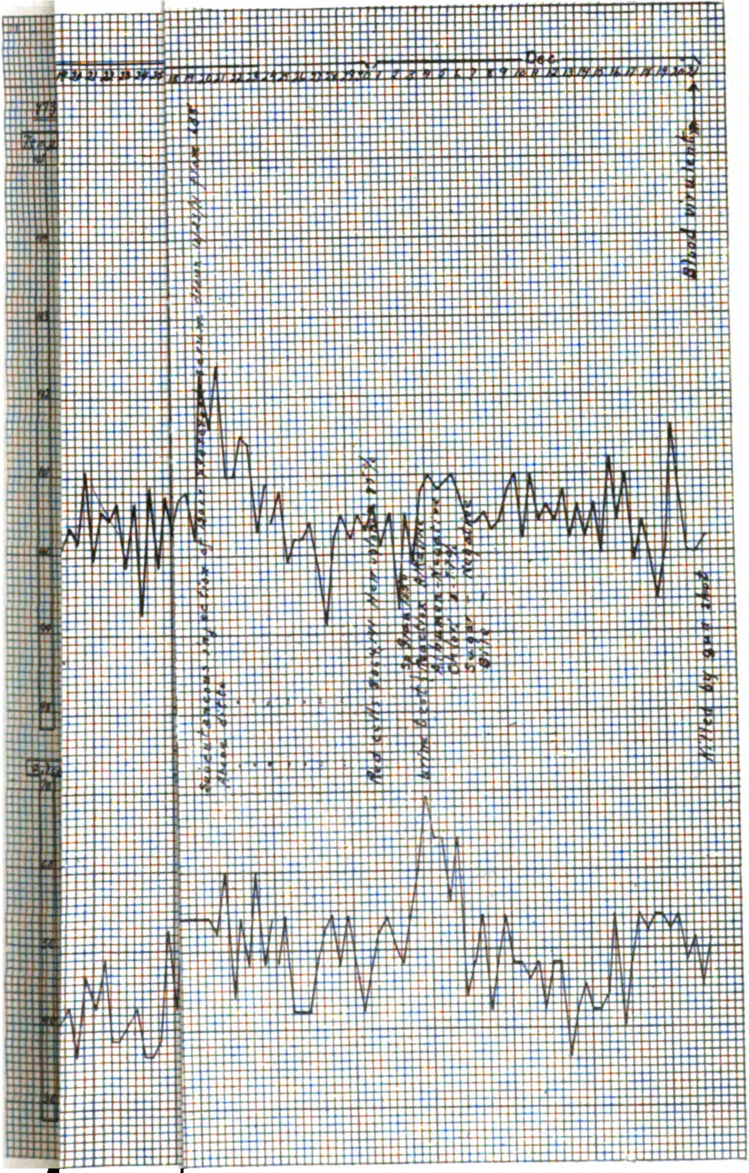


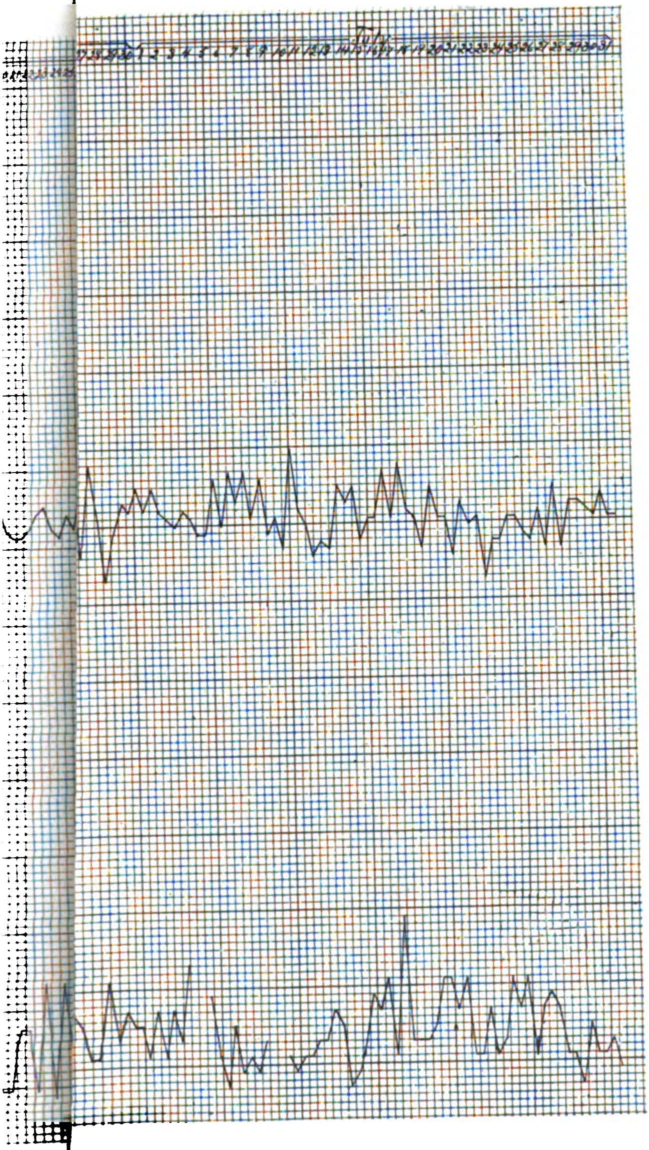
18 19 20 21 22 23 24 25 26 27
853
Temp
105
104
103
102
101
100
99
98
Puls
70
60
50
40
30
Mucosa still slightly blue
Pustules about neck and should
Skin yellowish and slightly
Mucosa still

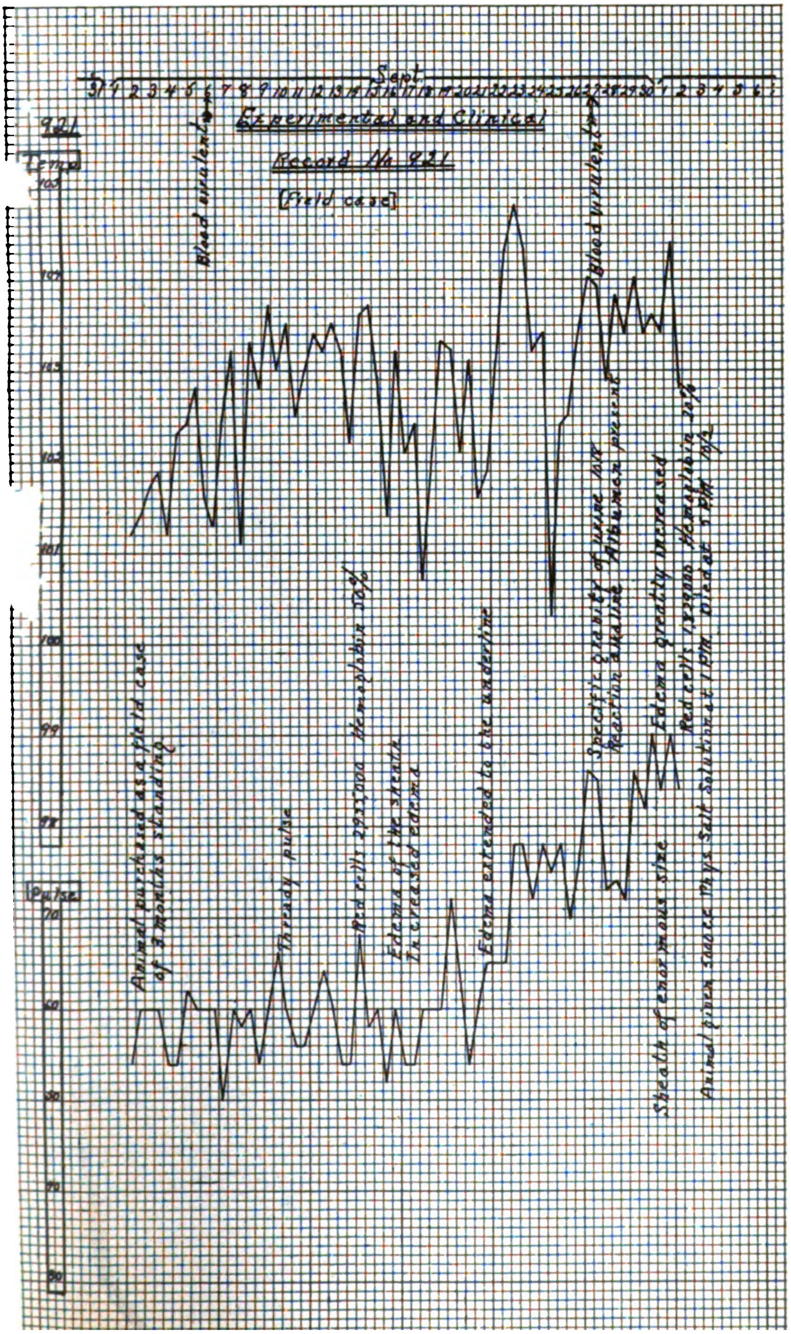

Experimental and Clinical Record of No. 640

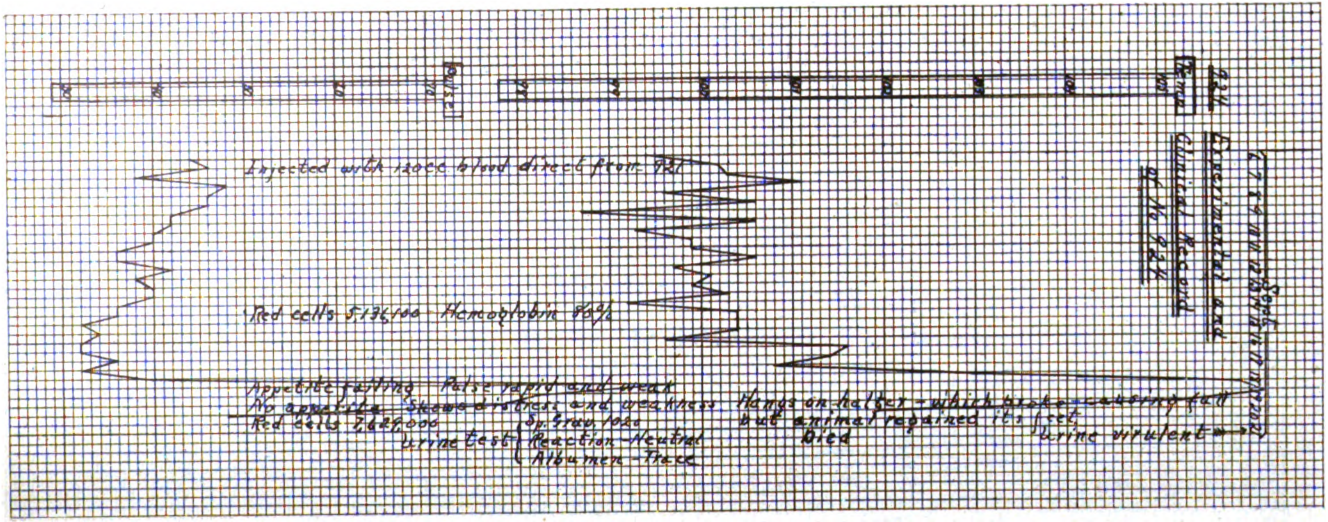
[Field Case]

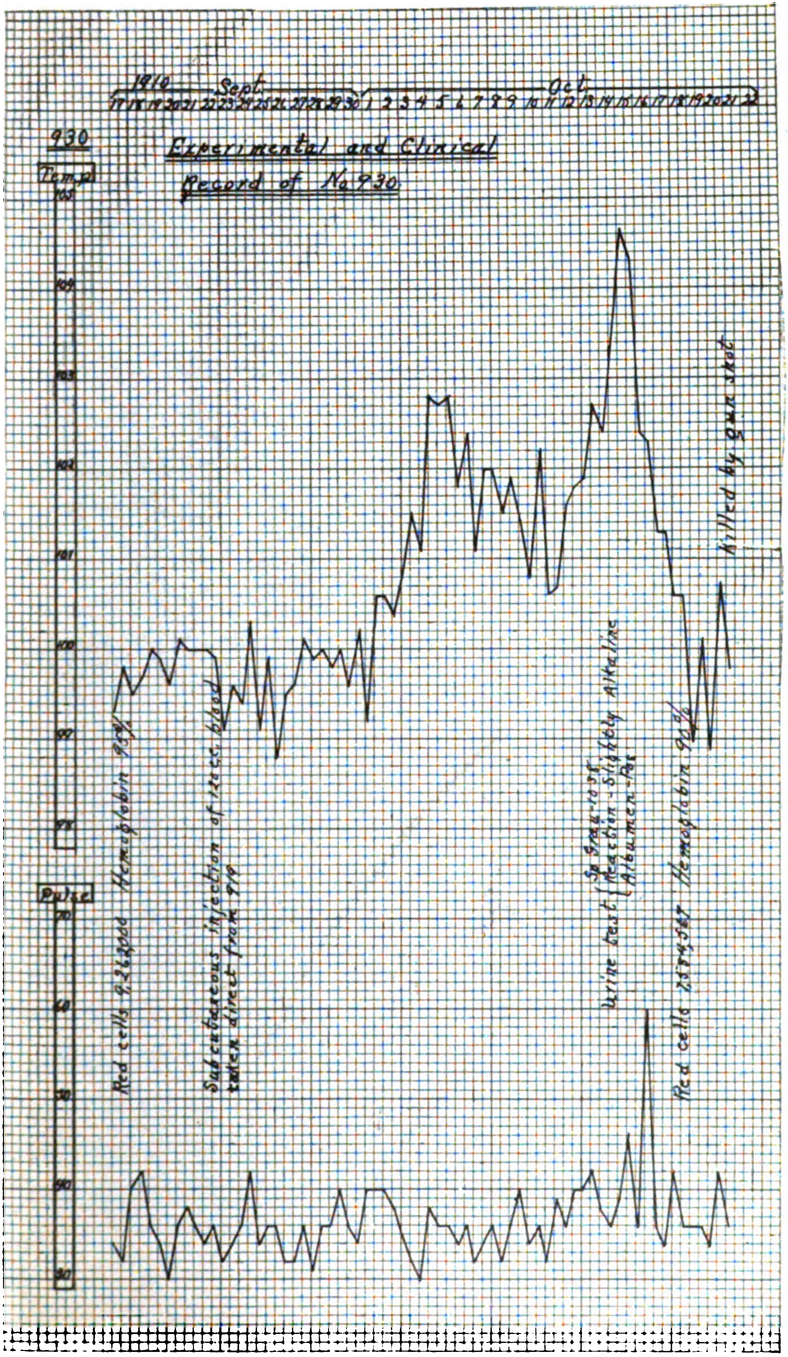

18 19 20 21 22 23 24 25 26 27
Mucosa still slightly blue
Pruritis about neck and shoulders
Skin yellowish and slightly edematous
Mucosa still shows blue ashy gray in color

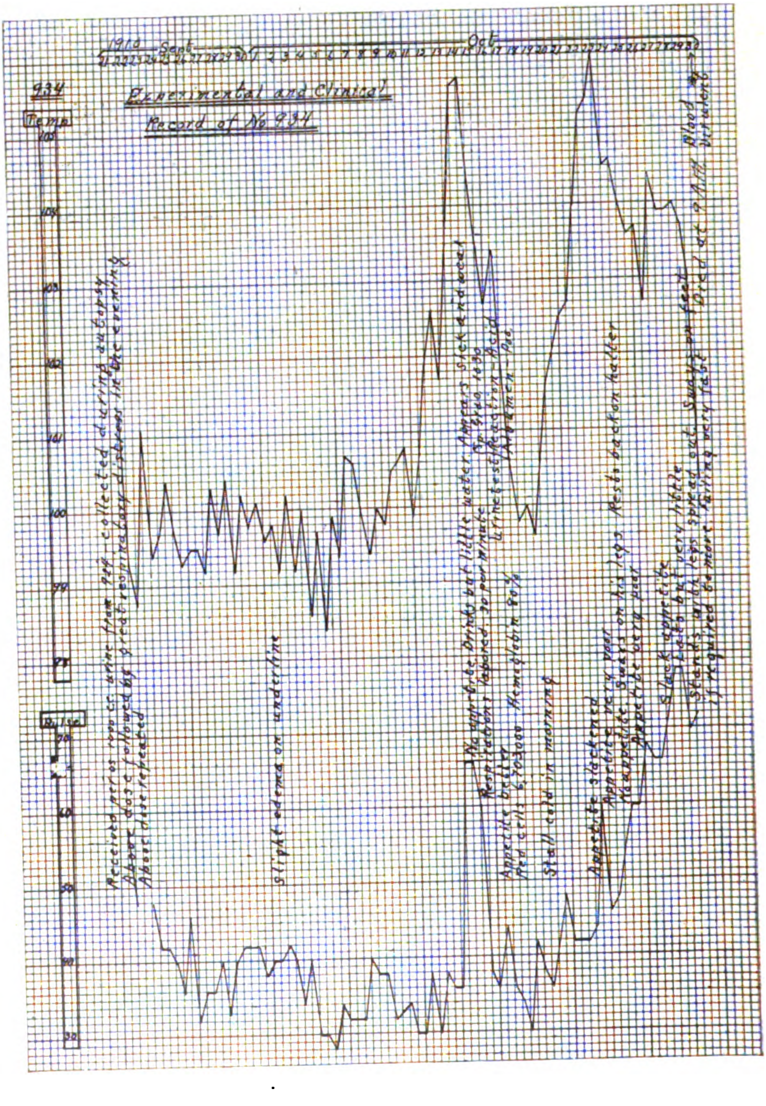

Temp
Dec
Subcutaneous injection of ... serum drawn ... from 488
Above ditto
Red cells ... Hemoglobin 75%
Urine test
Sp. Gra. 1030
Reaction Alkaline
Albumen—Negative
Chlori ...
Sugar — Negative
Bile —
Killed by gun shot
Blood virulent


July
21 22 23 24 25
27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


921
Temp
105
104
103
102
101
100
99
98
Pulse
70
60
50
40
30
Sept.
31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6
Experimental and Clinical
Record No. 921
[Field case]
Blood avirulent
Blood virulent
Animal purchased as a field case
of 3 months standing
Thready pulse
Red cells 2935000 Hemoglobin 30%
Edema of the sheath
Increased edema
Edema extended to the underline
Specific gravity of urine 1011
Reaction alkaline Albumen present
Sheath of enormous size
Edema greatly increased
Red cells 1832000 Hemoglobin 20%
Animal given 1000 c.c. Phys. Salt Solution at 1 P.M. Died at 5 P.M. 10/2


924
Experimental and
Clinical Record
of No 924
Sept.
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Temp
105
104
103
102
101
100
99
98
Pulse
70
60
50
40
30
Injected with 120cc blood direct from 921
Red cells 5,136,100 Hemoglobin 80%
Appetite failing Pulse rapid and weak
No appetite Shows distress and weakness
Red cells 2,628,000
Urine test
Sp. Grav. 1020
Reaction – Neutral
Albumen – Trace
Hangs on halter – which broke causing fall
but animal regained its feet
Died
Urine virulent

1910
Sept.
17 18 19 20 21 22 23 24 25 26 27 28 29 30
Oct.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
930
Experimental and Clinical Record of No. 930
Temp.
105
104
103
102
101
100
99
98
Pulse
70
60
50
40
30
Red cells 9,262,000 Hemoglobin 95%
Subcutaneous injection of 10 c.c. blood taken direct from 919
Urine test { Sp. Grav.-1038 Reaction - Slightly Alkaline Albumen - Pos
Red cells 2574587 Hemoglobin 90%
Killed by gun shot


934
Experimental and Clinical Record of No 934
1910 Sept. 21 22 23 24 25 26 27 28 29 30
Oct. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Temp.
105
104
103
102
101
100
99
98
Pulse
70
60
50
40
30
Received per os 1000 cc. urine from 924, collected during autopsy
Above dose followed by great respiratory distress in the evening
Above dose repeated
Slight edema on underline
No appetite. Drinks but little water. Appears sick and weak
Respirations labored, 30 per minute
Sp. Grav. 1030
Urine test Reaction - Acid
Albumen - Pos.
Appetite better
Red cells 6,703000 Hemoglobin 80%
Stall cold in morning
Appetite slackened
Appetite very poor
No appetite. Sways on his legs. Rests back on halter
Appetite very poor
Slack appetite
Eats but very little
Stands with legs spread out. Sways on feet
if required to move. Failing very fast
Died at 9 A.M. Blood virulent

MICHIGAN,
MAY 30 1912

NORTH DAKOTA
AGRICULTURAL COLLEGE

EXPERIMENT STATION
OF
NORTH DAKOTA

BULLETIN NO. 95

ALFALFA

PART I. Practical Information for Alfalfa Growers.
PART II. Studies in Drouth Resistance and Seed Production.

BY

L. R. WALDRON

Any farmer, teacher or student in the State may have this Bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
December 1911

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ALFALFA MAXIMS.

1. Alfalfa must be inoculated.
2. Alfalfa cannot stand wet feet.
3. Alfalfa needs a well drained soil.
4. Alfalfa is a poor weed fighter the first season.
5. Alfalfa does not thrive when not cut.
6. Alfalfa should be cut when one-tenth in bloom.
7. Alfalfa should not be cut too late in the season.
8. Alfalfa roots go deep.
9. Alfalfa is the prince of drouth resisters.
10. Alfalfa needs a deep, well packed seed bed.
11. Alfalfa does best on manured soil.
12. Alfalfa is best seeded without a nurse crop.
13. Alfalfa should be seeded with a drill.
14. Alfalfa should not be pastured until well established.
15. Alfalfa should not be pastured in the spring, when starting growth.
16. Alfalfa boards itself and pays for the privilege.
17. Alfalfa adds humus to the soil.
18. Alfalfa sod plows hard.
19. Alfalfa sod produces good crops.
20. Alfalfa yields are large.
21. Alfalfa hay represents quality.

GLEANINGS FROM THE BULLETIN.

1. Alfalfa demands a sweet, well-drained soil. North Dakota soils are of this character.
2. Alfalfa is naturally a drouth resisting and a drouth defying plant.
3. Those growing alfalfa should take care to secure the seed of hardy strains.
4. There are two fundamental factors necessary for successful alfalfa culture in this state; these are, inoculation and a well developed root system.
5. Equipped with these two factors, alfalfa will do as well or even better, accordingly, as any crop that can be grown.
6. Nearly all North Dakota soils must be inoculated with alfalfa bacteria.
7. Extension of successful alfalfa culture in North Dakota cannot go on faster than the extension of inoculated areas.
8. Each additional inoculated area forms a nucleus for the invasion of new areas.
9. Inoculation is most easily accomplished by using dirt from a successful alfalfa field.
10. Dark green, vigorous growth of alfalfa is good evidence of inoculation.
11. Alfalfa must be grown in comparatively thin stands in order that the plant may exercise its drouth resistant qualities.
12. The thickness of stand should be in direct relation to the amount of water available to the plant.
13. Other things being favorable, the thinness of stand is in direct relation to the well developed root system.
14. Grimm alfalfa is a very promising sort for North Dakota.
15. Alfalfa seed production is a promising industry for North Dakota.

PART I.

PRACTICAL INFORMATION FOR ALFALFA GROWERS

By L. R. WALDRON.

Judging from many observations, and from experiments that have been conducted, alfalfa will doubtless become one of the staple crops of North Dakota. This position of alfalfa will come about slowly, at best, for the general introduction of this legume into North Dakota will mean a considerable change in the methods of farming now in vogue. At the present time a large number of farmers desire to seed small areas to alfalfa. The success of these will have a beneficial influence upon the further extension of the crop.

There are difficulties connected with successful culture of alfalfa under all soil and climate conditions. Alfalfa has special difficulties to encounter in semi-arid districts, and these will be considered later in some detail. When one has mastered the requirements of alfalfa culture, the growing of it seems simple, for the crop responds promptly and favorably to right methods of treatment. One having apparent failure should, by treatment and inquiries, determine the cause. In nearly all cases, some modified method will bring success. The difficulty is generally not fundamental.

SELECTION OF THE LAND.

The soils, usually, in North Dakota, are favorable to the crop. but results will be secured more easily from certain soils or from some particular lay of the land.

As a general rule, one should commence with a rather small area. In the selection of this, attention should be paid to the fertility of the soil and to the moisture that will be available to the plants. As one becomes experienced in alfalfa culture, the alfalfa areas may be extended to the less favorable areas of the farm.

Most crops like a fertile soil, and a relative abundance of water. Alfalfa is no exception to the rule. This does not imply, however, that alfalfa will not be a paying crop with but moderately fertile soil, and with somewhat diminished supplies of water. Alfalfa makes the best showing possible with the fertility and moisture at hand. A marked character of alfalfa is its great adaptability. We have no extreme conditions in the state, except perhaps in the way of temperature. Alfalfa in other districts is considered a sure crop with conditions apparently less favorable than are ours.

The ideal alfalfa soils in North Dakota are limited, the limitation running most strongly to an insufficient water supply for the maxium yield. Farther on it will be shown that moderate cultivation of the crop aids in conserving a considerable portion of the rainfall, thus adding to the growth of the plants. As the moisture requirements for alfalfa are not excessive, the natural conclusion is that alfalfa will be as successful in North Dakota as any crop commonly grown.

A fertile soil, somewhat limy or alkaline, with a permeable well drained sub-soil will be found adapted to alfalfa. The advantage that "bottom" soils possess is that with such soils the moisture supply is more abundant. In North Dakota, such soils are generally well enough drained to grow alfalfa with success.

Ground with a light or sandy sub-soil is generally at a disadvantage as such sub-soils are not retentive enough of moisture. At times of drouth the alfalfa ceases to grow. The moisture, that would have been stored within reach of the alfalfa roots with a heavier soil, has leached away through the sand, leaving the soil dry. Our studies have shown that a comparatively thin layer of clay at a depth of several feet will act as a barrier against the leaching of moisture, so that the sand above the clay is moist in contrast to adjacent sand unsupported by layers of clay.

Soils that have a sub-soil of very dense, close texture may be unsuited as the alfalfa roots have difficulty in penetrating layers of hardpan, or dense "gumbo." Moisture penetrates such heavy sub-soils with difficulty, and as a consequence the alfalfa responds less readily after periods of drouth.

CROP TO PRECEDE ALFALFA.

Having selected a piece of ground upon which it is desired to grow alfalfa, one should consider the proper preceding crop. Scarcely without question, such a crop is a cleanly cultivated and manured crop of corn or potatoes. A cleanly tilled summer fallow is also efficient and is to be recommended in the drier areas. The clean cultivation given to the corn or potatoes conserves the moisture and reduces the weeds to a minimum.

At this point it may be well to discuss some of the features of alfalfa growth during the first season. Annual plants, such as the corn plant, make much growth above ground the first season, in addition to developing a root system. The alfalfa plant, on the other hand, devotes its main energy the first season to the development of a root system. The permanent value of the alfalfa stand is determined in considerable measure by the favorable conditions the alfalfa has the first season for the development of its roots.

One of the very important conditions for the development of the roots is a satisfactory supply of moisture in the soil. It is quite impossible for the growing root to penetrate a dry soil. The soil will normally contain considerable moisture after a corn or potato crop. Herein lies the value of a previously cultivated crop or summer fallow.

Under favorable conditions the root development the first season is quite remarkable In Colorado, alfalfa plants only 9 months old have been found with roots nearly 9½ feet long. At Dickinson plants 15 months from seeding have been dug with roots 8 feet or more long.

If alfalfa is sown is a soil having no excess water stored in the sub-soil, chances for the development of a good root system the first season are not good. The shallow rooting weeds, which are bound to appear to a greater or less extent, will take up much of the moisture as it falls, allowing but little to penetrate into the deeper layers of soil to benefit the young alfalfa plants. When no moisture has been stored from the previous season, the first year's alfalfa growth is stunted, and the condition of the stand may be permanently injured.

When sown on land with dry sub-soil, the roots penetrate for a few inches through the moist soil and then reach the dry, hard sub-soil, located perhaps at the bottom of the furrow slice. Being unable to penetrate the dry soil, the roots stop growth entirely, or perhaps run horizontally in the bottom of the furrow. Alfalfa is thus changed from a deep rooting to a shallow rooting crop. It is changed from a drouth resisting crop, which it normally is, to a crop unable to resist drouth. The root system of alfalfa is the life of the plant, and of the crop, and the best of conditions should be afforded for the development of the roots.

Too much emphasis cannot be placed on the necessity of sowing alfalfa on land with a moist sub-soil. If the subsoil is naturally moist, less care need be taken in conserving moisture the season previous. If one does not have land with a sub-soil moist to a moderate depth, then the planting of alfalfa should be postponed until the soil is put in fit condition in this regard.

Alfalfa is a poor weed fighter the first season. Weeds injure the young alfalfa plants by a direct smothering effect, and also indirectly by drawing the moisture from the soil that would otherwise be available for the alfalfa.

There is an added advantage in having the root system develop as much as possible the first season. Alfalfa well rooted the first summer is less liable to be injured during its first winter. It is generally believed that alfalfa is more liable to winter kill during the first than during subsequent winters.

PREPARATION OF THE SEED BED.

When alfalfa is grown on corn or potato ground, the preparation of the seed bed is a comparatively simple affair. The land should be disced in the spring and worked with a peg-tooth harrow. After the discing and harrowing the ground should be worked occasionally during the spring with disc and harrow in order to conserve moisture and to kill the young germinating weeds.

Growing the alfalfa after a corn or potato crop is of added advantage in that the seed bed is firm below the top two or three inches. The small seed of the alfalfa and the delicate nature of the young plant demand a compact seed bed, in comparison to what is allowable for corn or even for wheat.

In an open, porous seed bed the soil is apt to dry out in the upper few inches, and if this occurs shortly after the germination of the alfalfa, the young seedlings are quite liable to die through lack of moisture.

If alfalfa is to be grown after a crop of small grain the land should be fall plowed. The fall plowing allows the seed bed to become more compact than spring plowing, and in addition, aids in conserving moisture. The fall plowing should be worked in the spring in much the same manner as the corn or potato ground. Alfalfa may be grown upon summer fallow, though this probably has no advantage over corn ground in most instances.

USE OF A NURSE CROP.

This is one the points considered by nearly every farmer when preparing to grow alfalfa. When alfalfa is sown under the conditions indicated previously, upon clean corn or potato ground, then a nurse crop is a damage to alfalfa provided that tumble weeds do not invade the land. When alfalfa is sown on land rather weedy then the sowing of not over 2 or 3 pecks of barley to the acre, to be cut for hay may be admissable. As far as alfalfa is concerned, the nurse crop is of value only as a substitute for weeds. The introduction of a nurse crop merely gets rid of one evil by introducing another. Occasionally the evil introduced is the lesser. Unfortunately over much of North Dakota the Russian thistle invades the land each year from neighboring farms so that cleanly cultivated land becomes foul each season.

Some farmers report having used a nurse crop with alfalfa with good results, but where the conditions are favorable for alfalfa a nurse crop should not be used. As a general thing the seeding of alfalfa should be postponed until the field conditions are favorable.

Farmers commonly use oats as a nurse crop. This is a poor crop to use, as it makes greater drafts on the soil moisture than either wheat or barley. Its strong stooling habits are also objectionable.

CHOICE OF SEED.

When choosing alfalfa seed, much the same rules apply as with seed of other crops. One should secure clean, plump seed, of good color, and with good germinating ability. Fresh alfalfa seed is a dull yellowish-green, and with age the color becomes brownish. According to good authority, alfalfa seed does not readily lose its ability to germinate. If one desires to find out about the germination of any sample of seed, 100 seeds should be counted out and kept between moist blotting paper for a few days, or the sample may be sent to the Seed Commissioner, Agricultural College, N. D., for germination and purity tests.

Alfalfa seed is occasionally, though not commonly, adulterated. Seed of sweet clover is sometimes found mixed with alfalfa seed as an adulterant. The seed of the ribbed or English plaintain, a noxious weed of the eastern states, is quite often found in alfalfa. The most pernicious weed seeds found in alfalfa are the seeds or dodder.

DODDER.

The dodder, or love vine, is a parasitic plant very injurious to alfalfa and clover fields. There are at least three kinds of dodder infesting alfalfa, the most common one of the western states being the small-seeded dodder. The seed of this dodder is readily removed from alfalfa seed by means of the fanning mill. The seeds of the clover dodder are large, being nearly as large as alfalfa seed. Alfalfa seed containing the seed of clover dodder is difficult to clean, but most of the clover dodder may be removed by hand sifting if the work is done thoroughly and with care.

Alfalfa seed, like all other seed intended for farm sowing should be well cleaned and graded before being sown. If proper care is exercised very many of the noxious and other weed seeds, as well as much inert material, may be removed from the alfalfa seed by means of the fanning mill. When graded in this manner the seed feeds more uniformly through the drill.

The sale of alfalfa or other seeds in North Dakota, containing dodder seed, is strictly prohibited by law, and any suspected cases should be reported to the Seed Commissioner, Agricultural College, No. Dak.

HARDY ALFALFA.

In buying alfalfa seed much care should be taken in reference to hardiness of the strain. It is a mistake to buy southern grown alfalfa seed as it is pretty sure to be lacking in hardiness. Alfalfa seed grown in the north may or may not possess hardiness. It is a mistaken idea to believe that Montana grown seed, for instance, necessarily has hardiness. The growing of alfalfa for one or two generations in Montana may not bring about any marked degree of hardiness.

A variety of alfalfa has been produced which is very hardy. This is the well known Grimm alfalfa, and whenever possible the seed of the Grimm should be sown for alfalfa growing in North Dakota.

INOCULATION.

A factor preventing the rapid extension of alfalfa areas in North Dakota is the necessity of inoculation. This has a retarding influence in two ways. The farmer sows alfalfa and finds it is not a success; he becomes discouraged and does not try again. In addition to this discouraging effect, the labor necessary for inoculating large areas of land is not inconsiderable; but inoculation must be present before alfalfa will thrive.

This inoculation, it should be explained, means the introduction of certain bacteria or germs into the soil. These germs grow in nodules or enlarged growths on the roots of the alfalfa plant. See Fig. 1. When these are not present the alfalfa is ordinarily unthrifty, especially after the first year.

Certain low lying soils in the state, especially those that have had applications of barnyard manure may not need inoculation with the alfalfa germs, but ALMOST WITHOUT EXCEPTION NORTH DAKOTA SOILS MUST BE INOCULATED FOR SUCCESSFUL RESULTS WITH ALFALFA. Time spent in experimenting on this point is the same as time wasted.

METHODS OF INOCULATION.

The simplest and surest method of inoculation is to secure dirt from some successful alfalfa field and scatter it broadcast over the land intended for alfalfa. There are two or three simple directions that should be observed here. The amount of dirt necessary for inoculation is 100 to 200 pounds per acre. To aid in distribution the alfalfa dirt may be mixed with its volume of other dirt, to increase the bulk. The soil to be used for inoculation should not be allowed to dry out. The application should be made on a cloudy day, and the inoculating soil should be harrowed in soon after being applied. If the soil containing the germs is allowed to dry out, or if exposed to sunshine, the germs will be killed.

Pure cultures can be purchased of dealers, but these generally require more careful treatment than the average farmer would care to give them.

The alfalfa dirt suitable for inoculation may be secured from the central station at Fargo, or from the Dickinson station at a cost to cover sacking, 50 cents per 100 pounds.

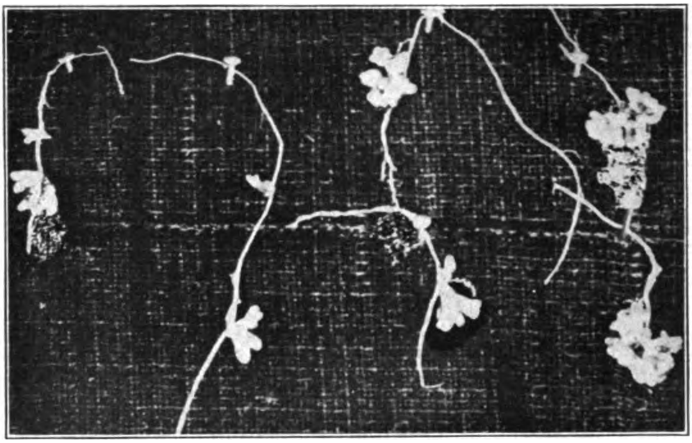


Fig. 1. Shows alfalfa nodules upon the small roots. Note their fan-like appearance. (Natural size.)

TIME OF SOWING.

As the young alfalfa plants are easily injured by frosts, and by weeds, it is best not to sow alfalfa early in the spring. Alfalfa seeding may be delayed until other crops are in. There is no advantage in sowing alfalfa before the middle of May, and if the land is weedy the seeding may be delayed until the middle of June. By this time the majority of weed seeds can be germinated and killed.

METHOD OF SOWING.

Alfalfa seed is best sown with a drill. If sown in such a manner, less seed is required per acre and the seed that is sown is covered to a more uniform depth.

Northern grown seed, and especially Grimm seed, is expensive, and this reduction of the amount required means considerable saving of money. The seed may be sown either from the grain box, or by means of a grass seed attachment, usually obtained with drills. Some makes of drills have alfalfa plates to fit into the grain holes, and by means of such plates the rate of seeding can be so reduced that 15 pounds of alfalfa seed can be sown per acre without diluting the seed with some foreign material.

If the drill cannot be made to feed the seed slowly enough the seed may be mixed with ground feed, boiled and dried millet seed, or better still, with alfalfa dirt. If alfalfa dirt is used for dilution it should be dry enough to allow the mixture to run easily through the drill. When not too dry it has a slightly retarding action on the flow of the seed. When too moist the dirt cakes and the seed does not feed properly unless a force feed drill is used.

SEEDING BROADCAST.

If broadcast seeding is done, the seed may be sown by hand, or better still by a wheelbarrow seeder. The seed is covered with a harrow. Broadcast seeding requires one-third more seed than does drill seeding.

AMOUNT OF SEED TO SOW.

Using a standard quality of seed, the proper amount to sow varies with the amount of moisture available to the alfalfa plants. For this state, 5 to 10 pounds of choice, hardy seed per acre, evenly distributed at a uniform depth, will furnish a sufficiently heavy seeding. Five pounds of seed per acre is probably a sufficient amount over large sections of the state, when all conditions are favorable. The cutting down of the expense by sowing this small amount of seed is an item of some importance. The increased quality of stand, secured by thin seeding, is much more important.

It will be shown in the second part of this bulletin, a thin stand for certain conditions produces a much larger yield than a thicker stand. Practically all of the alfalfa seeding in the state up to this time has been at a comparatively heavy rate; 15 pounds or more of seed per acre. In a few instances those growing alfalfa recognize that too much seed has been used per acre, and some of them believe that 5 pounds of seed per acre is sufficient.

In Montana and Washington it is recognized that alfalfa must be seeded thinly if success is to be obtained. Max Hinrichs, of Pullman, Washington, recommends that not more than 5 pounds of choice seed be sown to the acre.

DEPTH OF SEEDING.

Alfalfa should not be seeded deeper than 2 inches in light soils. In clay soils, a depth of one inch, or less, is sufficient. The seed germinates rapidly and the crop should be well up in 5 days, under favorable conditions. In sandy soils, lacking humus, or in clay soils, a rain coming before the alfalfa is up will allow a crust to form on the surface of the soil, which is penetrated with difficulty by the seedlings. Unless this is broken, considerable injury will ensue.

A very light, wooden roller may be made of inch boards, with small nails driven through the boards to project to the outside. Running this roller over the surface will break the crust, but not materially injuring the alfalfa.

CARE THE FIRST SEASON.

Alfalfa does not require much care the first season. If weeds come up thickly, as they usually do, it is well to clip the alfalfa, tilting the mower bar and running it high. Care should be taken not to cut the alfalfa too short. The field may be clipped two or three times during the season, as necessity arises. If the alfalfa is sown on low ground it may be necessary to remove a crop of hay. This should be done early enough so that the alfalfa will make good growth after cutting. Ordinarily the clippings may be left upon the ground. The alfalfa is liable to be injured when clipped too young. It is generally recognized that alfalfa stubble should have sufficient height at the beginning of winter to afford protection to the plants by the catching of snow. Prof. Thomas Shaw states that under his direction, in Montana, alfalfa was harrowed the first season with distinct advantage. Such harrowing cannot be done until the roots are fairly well established.

TREATMENT THE SECOND SEASON.

In the spring of the second season the alfalfa may be benefitted by harrowing or perhaps a light discing. A machine known as the alfalfa renovator is being used to a considerable extent. This is shown in Fig. 2. The cultivation of the alfalfa aerates the soil, tends to destroy the weed growth, conserves the moisture and works the fallen alfalfa leaves, lying upon the ground, into the soil. The working up of the surface, making it rough, also tends to prevent the run-off from rains.

TIME OF CUTTING FOR HAY.

An old established rule is to cut alfalfa when one-tenth in bloom. Alfalfa at this stage has a higher percentage of protein than if cut when older. Thus the hay is richer and also more palatable. About the time of bloom the basal shoots are just starting from the crown, and alfalfa cut at this time allows the young shoots to come on rapidly When the alfalfa is cut too early, the growth of the young basal shoots is said to be delayed. If the hay is cut too late, the basal shoots are cut off and the second growth is severely injured.

When alfalfa is cut at the time of one-tenth in bloom, it was found that the total hay yield for the season was greater than when the cuttings were made when the hay was in full bloom. The yield from the first cutting was larger, but the yield from the next cutting was enough less to more than offset the increased yield of the first cutting. When the cutting of alfalfa is delayed, some of the lower

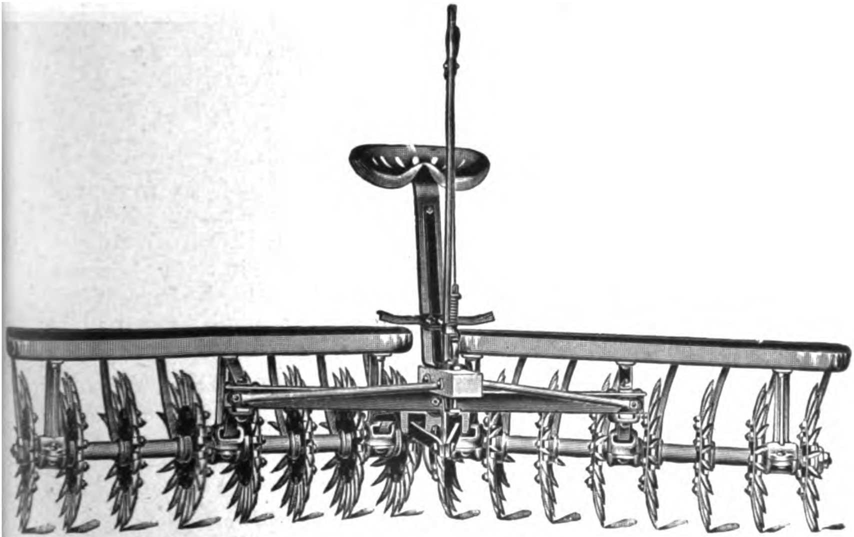


Fig. 2. Alfalfa renovator, a tool used to a considerable extent in cultivating alfalfa fields in alfalfa districts.

leaves mature and fall off. The leaves form the richer portion of the hay, and every effort should be made to retain the greatest amount of leaves possible. The tenth-in-bloom rule is a pretty safe one, but it is an easy matter to examine the crowns of the alfalfa plants to see if the new shoots are making a start. If they are, it is time to start the mower.

MAKING THE HAY.

A little study shows why great care should be exercised in making alfalfa hay. Unlike true grasses, the leaves readily fall from the alfalfa plant as soon as they are dry. Leaves are the richest portion of the plant and contain much the higher percentage of protein. Without the leaves, the alfalfa plant would be but little more valuable than ordinary grass hay. Great care then should be exercised to save all the leaves possible in making alfalfa hay.

After the plants are cut, while the leaves are wilted, but before they are dry, the leaves draw the moisture from the stems of the plant. As soon as the leaves become dry they cease drawing moisture from the stem. Therefore hay is best cured if the leaves are left in a wilted condition. This is brought about by allowing the hay to cure in absence of sunlight. A large part of the curing should be done, then, in the windrow and in the cock. When the hay is allowed to cure in the swath, even the necessary handling of the hay to get it onto the wagon brings about a great loss of leaves. This loss should be prevented whenever possible.

With these principles in mind, the alfalfa hay, if cut in the morning, and with a yield of 1 to 1½ tons per acre, will be ready to rake and bunch in the afternoon, if conditions for hay making are good. With a light cutting of alfalfa, the rake may follow the mower within 3 or 4 hours. The hay should be raked up while still green, before it has become dry. A good share of the curing should take place in the cock. Bunching is best done by hand, as bunching with the rake wastes considerable of the hay, and the bunches, when so made, are not in as good a condition to turn water. If the crop is light, the hay may be drawn the same day it is cut. With an average yield, the hay may be drawn the second day after cutting.

Rain does great injury in causing loss of alfalfa leaves which form so valuable a portion of the hay. Not only is there an absolute loss of the leaves, but the rain dissolves out some of the protein from the leaves. Alfalfa hay may be drawn before it is entirely dry, as it will do some of its curing in the stack or mow. Cock covers may be made out of muslin, 36, or better, 45 inches square. The center of the cover may be painted to turn water. The corners should be weighted. As a general rule, not more than two cuttings annually will be secured from alfalfa in North Dakota. The second cutting should be made at relatively the same time as the first cutting,—in early bloom. When the hay is intended for horses the cutting may be made when the alfalfa is in full bloom.

Alfalfa should not be cut so late that it will be unable to make some recovery before the end of the growing season. The growth made by the alfalfa after the last cutting protects the plants by catching snow. Grimm alfalfa will not need this protection as much as alfalfa commonly sown, but even with Grimm, catching of snow is of value in wetting the ground.

STORING OF ALFALFA.

Alfalfa hay stored in the barn is subject to the least loss, where litter from the mow can be utilized, which is not so easily done when hay is stacked. It is stated that the loss of alfalfa hay when stacked is about 10 per cent greater than when stored in the mow.

An alfalfa stack should have protection at the bottom as well as at the top. Old posts or stone placed upon the ground and covered with straw or old hay is of decided value under the stack. If the alfalfa hay is placed directly upon the ground the moisture from the soil, or water from melting snow and heavy rains is sure to injure a considerable amount.

An alfalfa stack does not turn water at all well, so in finishing up the stack it should be covered with old hay, slough grass, or some such material.

Stock should be prevented from running to the stack, as otherwise much hay would be wasted. One should bear in mind that good alfalfa hay is worth twice as much as ordinary hay, and corresponding care should be taken.

If alfalfa hay is stored in the mow or stacked too green, spontaneous combustion may occur when the weather conditions are favorable.

Alfalfa is successfully baled, though in baling a considerable portion of the leaves is liable to be lost. Hay for baling must be pretty thoroughly cured, so that baling from the field is generally not to be advised. A hollow bale is made which is less liable to heat.

Alfalfa need not be so thoroughly cured when stacked as when put into the mow. Alfalfa may be stacked when the drying has proceeded to such a stage that the water will not come from the twisted stems of the hay.

MANURING ALFALFA STUBBLE.

Top dressing an alfalfa meadow is of advantage, and this is best done in late fall and early winter. The manure serves as a fertilizer to the alfalfa, and in addition, affords some winter protection. The presence of the manure upon the alfalfa delays the early spring starting of the plants, thus obviating injury that might be done by spring frosts.

PLANT FOOD REMOVED FROM SOIL.

The following table gives the weight in pounds of some of the plant food elements removed by the alfalfa hay crop and by a wheat crop. The amount removed is based on a ton of crop.

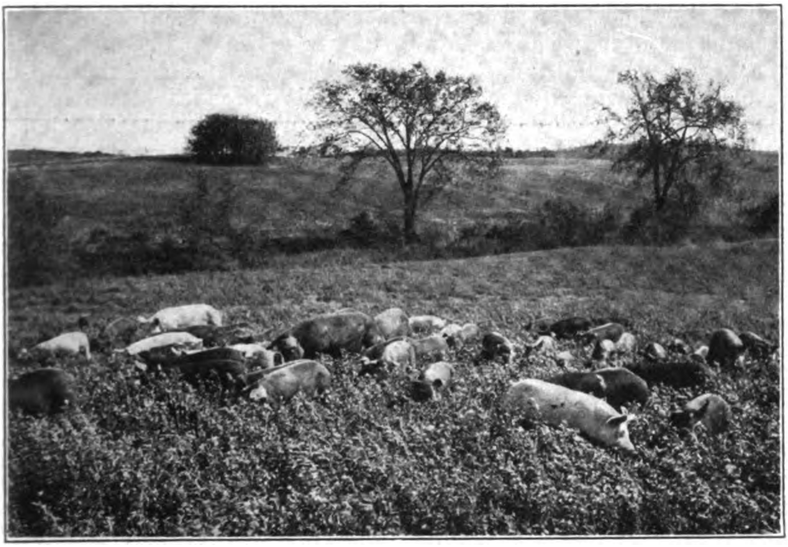
	Alfalfa hay crop	Wheat crop
Potash	48.79	12.52
Phosphoric acid	8.27	9.08
Lime	43.51	2.95
Nitrogen	44.01	22.30

The alfalfa is seen to draw much heavier on the soil than wheat, as far as potash and lime are concerned. The nitrogen is of less moment as considerable of this is derived from the air.

ALFALFA AS A PASTURE.

Alfalfa is primarily a hay plant, but the crop is of considerable value as a pasture. When an alfalfa field is to be used for both hay and pasture, care should taken to let the alfalfa become well established before pasturing. This means that the crop is not to be pastured until the third season. By the third season the alfalfa crowns will better stand tramping and close pasturing without serious injury. During the first and second season, the tramping of the stock will injure the alfalfa enough to offset the value gained by pasturing.

When alfalfa is planted solely for pasture, then the injury to the stand may be allowable. It must be understood when pasturing is done at improper times that the alfalfa hay stand will be injured. When desired expressly for pasture it is generally advised to sow the alfalfa in connection with tame grasses, such as timothy or brome grass. This is particularly true if the pasture is designed for cattle and sheep, as the mixture tends to prevent bloating.



Courtesy of A. B. Lyman.

Fig. 3. Swine pasturing on the fourth crop of Grimm alfalfa upon a Minnesota farm.

Alfalfa is particularly adapted as a hog pasture. See Fig. 3. The hogs do not eat the plant close to the ground, as do sheep and horses. The tramping of the alfalfa given by hogs is not severe. Oftentimes there is considerable growth in the fall after the second cutting, and this growth will run a number of hogs during the late fall. Enough of the alfalfa stems should be left to catch the snow. Hogs do not bloat upon alfalfa pasture, which is a point of importance.

Horses are rather injurious to alfalfa, due to their habit of close feeding. The same point may be made with sheep. Cattle and sheep are liable to bloat upon alfalfa, and for this reason care must be taken when these ruminants are first turned into the field. In other states the more careful farmers are of the opinion that a pure stand of alfalfa is rather too risky as a pasture for cattle and sheep. A patch of alfalfa makes an excellent poultry range.

ALFALFA MEAL AND ENSILAGE.

During recent years considerable alfalfa meal has been manufactured. Choice alfalfa hay is taken and reduced to a very fine condition. An advantage of this is ease in shipment, and when fed on the farm it is fed with less waste, and less energy of the animal is required in its mastication and digestion. In the east, the meal is mixed with other concentrates, such as molasses, the idea being to form a more balanced ration. Some large alfalfa growers have mills of their own and report a considerable saving by grinding.

Alfalfa is occasionally used as ensilage, and in some places corn and alfalfa are run in to the silo together. Alfalfa is of some value as a soiling crop, but it has only limited use for this purpose. It is stated that wilted alfalfa does not cause bloat.

THE VALUE OF ALFALFA AS A FEED.

A few words should be said on this point, more particularly in order to stimulate farmers to start the culture of alfalfa. The appreciation of the high character of alfalfa as a feed and the knowledge of its excellent yielding qualities will excite an interest in the plant that would not otherwise be taken. Without exception, alfalfa is the most highly nutritious and palatable roughage feed that can be grown in the state as a staple crop. The high value of alfalfa is due to the amount of protein that it contains, to the large percentage of the protein that is digestible and to the palatability of alfalfa.

The protein content is so high that alfalfa may rightly be considered a dual-purpose feed; at one and the same time, it is a roughage feed and a concentrate. It will not only take the place of ordinary hay, but it may be used as a substitute for wheat bran, or linseed meal. With but little study and care, the feeder can form a balanced ration producing gratifying results.

Tables are given showing composition and other data for alfalfa and other hays, and also for wheat bran. These are compiled from Henry's "Feeds and Feeding" and other sources.

AVERAGE PERCENTAGE COMPOSITION OF ALFALFA AND OTHER FORAGE CROPS.

Kind of Forage	Number of Analyses	Ash	Protein	Crude Fiber	Nitrogen-Free Extract	Ether Extract (fat)
Alfalfa hay	21	8.1	15.6	27.3	46.6	2.4
Clover hay	38	7.6	14.5	29.1	45.	3.9
Timothy hay	68	5.0	6.8	33.4	51.8	2.9
Prairie hay	1*	8.0	7.5	28.0	52.	4.5

*This is evidently a good quality of prairie hay as regards analysis. Its protein is as high as samples of Colorado prairie hay or as high as very many South Dakota native grasses. This sample came from eastern North Dakota.

AVERAGE PERCENTAGE OF DIGESTIBILITY OF ALFALFA AND OTHER FORAGE CROPS.

Kind of Forage	Protein	Crude Fiber	Nitrogen-Free Extract	Ether Extract (fat)
Alfalfa hay	73	43	66	54
Clover hay	55	49	69	53
Timothy hay	48	52	63	57
Prairie hay*	62	59	57	47

*Colorado bulletin No. 93.

DIGESTIBLE NUTRIENTS IN ALFALFA AND OTHER FORAGE CROPS.

Kind of Forage	Dry Matter in 100 Pounds	Digestible Nutrients in 100 Pounds		
		Protein	Carbohydrates	Ether Extract (fat)
Alfalfa hay	91.6	10.4	39.6	1.2
Clover hay	84.7	6.8	38.4	1.7
Timothy hay	86.8	2.8	43.4	1.4
Prairie hay	93.9	4.4	43.3	1.9
Wheat bran	88.1	12.2	39.2	2.7

The foregoing tables show the superior value of alfalfa hay when compared with clover, timothy or prairie hay. This statement applies particularly to the protein, as the other hays have an abundance of the cheaply produced carbohydrates in their make up. Protein is the expensive food element, as is indicated by the high price commanded by wheat bran, linseed meal, cotton-seed meal and other concentrates. Alfalfa hay is rather more of a concentrate than a roughage, as good alfalfa hay has too much protein to secure the best results in average feeding. For fattening stock it must be diluted, so to speak, with the cheaper carbohydrates.

To put the matter more concretely, a chart is presented showing the comparative value of prairie hay, alfalfa hay and wheat bran, with respect to the three food elements, protein, carbohydrates and fats.

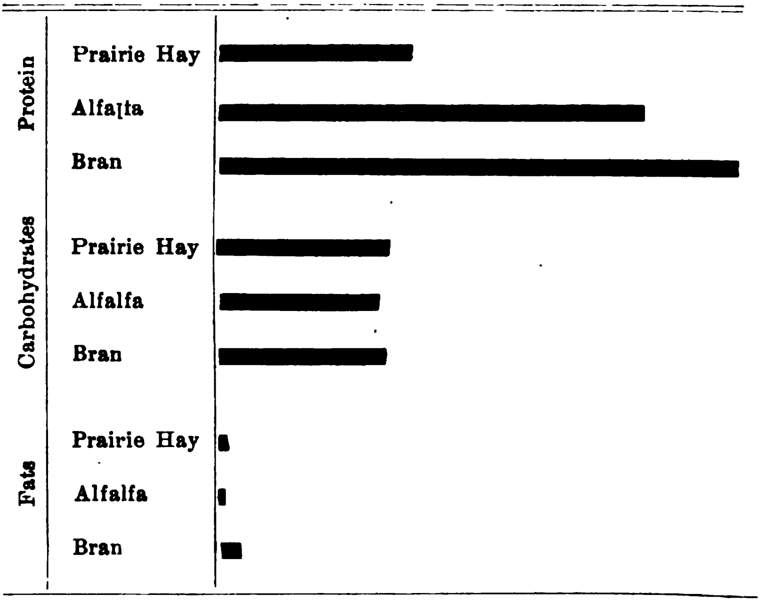


Chart 1. Shows graphically the comparative values of prairie hay, alfalfa hay and wheat bran, based upon their analyses, in connection with the market values of the food elements; protein, carbohydrates and fats. Note the relative richness of protein in the alfalfa hay.

The values in the chart are based on the analysis of the feeds, taken in connection with the money value of the food elements. This chart shows that the protein content of alfalfa approaches to that of wheat bran more closely than it does to prairie hay. When calculated to a ton basis, the five feeds given in the table would have the following money values:

Kind of Feed	Value per Ton
Timothy hay	$ 8.60
Prairie hay	10.60
Clover hay	12.90
Alfalfa hay	17.25
Wheat bran	19.65

VALUES WORK OUT IN PRACTICE

During the last 20 years, a very large number of experiments have been conducted with alfalfa in comparison with other feeds. Practical farmers have found that the experiments work out nicely on the farm. Almost without exception, they agree in giving alfalfa a peculiarly high value as a feed. Even when used alone it has given a good account of itself, though, as stated, it is not in itself a balanced ration. The citation of but a few of these experiments will suffice to show the feeding value of alfalfa.

ALFALFA FOR CATTLE.

In Kansas it was found that in feeding steers with corn-and-cob meal and alfalfa hay, the cost of 100 pounds of gain was $5.13. With corn-and-cob meal and sorghum hay the cost of 100 pounds of gain ran up to $9.06. The average profit per steer on the corn-and-cob meal and alfalfa hay ration amounted to $8.98. The average loss per steer with the corn-and-cob meal and sorghum hay ration amounted to $1.66, a difference between the two rations of $10.64 per steer.

In Nebraska a comparison was made between corn and prairie hay against corn and alfalfa hay for feeding two-year old steers. The results are the average of three experiments. The cost of 100 pounds of gain with corn and alfalfa amounted to $6.29. For the same amount of gain with corn and prairie hay, the cost was $8.32. The profit per head from the corn and alfalfa fed steers was $5.02, but from the corn and prairie hay fed steers the loss was 27 cents per head.

An experiment was carried out in western Nebraska at the North Platte experiment station, in feeding alfalfa and timothy hay to calves during the winter for the production of baby beef. The two lots of calves had the same grain ration. The calves were fed all the roughage they would eat. The following summary gives some of the results:

	Calves fed on alfalfa hay	Calves fed on prairie hay
Hay fed to each calf per day, lbs.....	12.3	10.9
Hay required for each 100 pounds of gain	1000.00	1676.00
Grain required for each 100 pounds of gain	162.00	305.00
Cost of 100 pounds of gain	$2.82	$4.51

The results show a feeding value of $5.80 per ton for prairie hay and $8.96 per ton for alfalfa hay. Thus the alfalfa hay was worth 2½ times as much for feeding as the prairie hay. At the time the experiment was conducted prairie hay could be purchased for $3.00, and alfalfa hay for $3.50 per ton.

It may be well to cite a conclusion found in Nebraska bulletin No. 90. "Alfalfa hay is pronouncedly superior to prairie hay for beef production, and the more rapid extension of land devoted to the production of alfalfa, supplanting the less valuable and lower yielding native hay, the more rapid will be the production of wealth from our soil."

In certain cases it has been found advisable to add a little corn stover to the alfalfa when corn is the grain, as the alfalfa used alone as a roughage may be too loosening.

ALFALFA FOR MILK PRODUCTION.

Alfalfa is of great value as a milk producer, for it is a well known fact that an ample milk flow requires rich feeds. Good June pasture produces an abundance of milk. It has been demonstrated that alfalfa hay, when used with a proper kind of grain, and with a little succulence, such as ensilage, will practically duplicate a June pasture.

When cows are properly fed, before turning onto pasture, they show no increase of milk flow upon the pasture. If a dairy cow is properly fed, she must have a ration that contains a larger percentage of protein than is found in common hays or in most of the grains. Protein is supplied through bran, linseed meal or some other concentrate. To pay high prices for these to increase the milk flow means that the cost of milk production is increased, and in many cases to such an extent that milk is produced at a loss, or at a very nominal margin.

ALFALFA A HOME GROWN CONCENTRATE.

The great value of alfalfa lies in the fact that the farmer can produce a concentrate upon his farm at a low cost, to take the place of the high priced concentrates purchased in the markets. Practical dairymen know the effect of adding wheat bran to the ration of the dairy cow, deficient in protein. A decided increase of milk flow is immediately brought about. Alfalfa has the same effect. Each pound of wheat bran is equivalent to 1¼ pounds of choice alfalfa hay.

After an alfalfa crop is once established, alfalfa hay can be produced as cheaply as other hays.

In addition to increasing the milk flow, alfalfa is excellent for keeping cows in good condition. Combinations may be made, of high priced feeds, that will produce as much milk as will a ration containing alfalfa; but such high priced rations are not apt to keep the cows in such splendid physical condition as does alfalfa.

The palatability of alfalfa is an important point in its favor. Cows will very often leave prairie pasture, even in June, to eat alfalfa hay. A cow considers alfalfa such a delicacy that one may depend upon her eating a considerable amount after having been on good pasture during the day.

When alfalfa forms an essential element in the ration of a dairy cow, the increased vigor produced will make the cow more resistant to diseases, such as tuberculosis, and stronger, healthier calves will be born.

RESULTS OF EXPERIMENTS.

The New Jersey experiment station found that when purchased feeds (concentrates) are figured at $25.00 per ton, then alfalfa hay is worth $16.50 per ton to feed with corn silage. The same station determined that including the cost of fertilizers, rent, etc., it cost $6.00 per ton to produce alfalfa hay, hence for each ton of alfalfa grown and fed by dairymen, there was a net profit of $10.50, in preference to the purchased feeds.

As an average of three experiments it was found that alfalfa hay, as an essential portion of the dairy ration, made a saving in cost of milk production of 28 per cent, and a saving in cost of butter production of 27 per cent, over a ration containing purchased feeds.

The Illinois station found that each ton of alfalfa hay fed to the cows produced a milk flow of 834 pounds over and above the milk flow of the cows fed on the same amount of timothy. The two lots of cows received the same grain ration. Each ton of alfalfa hay had an increased value over the same amount of timothy hay for milk production of $10.48.

No trials have been carried out in North Dakota, regarding the milk producing qualities of alfalfa, but similar results could be expected in this state. There is no doubt but that choice prairie hay, when fed with grain and a succulent feed, would produce a good milk flow, but alfalfa hay would be appreciably superior in this regard, and taken in connection with its increased yield, its increased value per acre would be very considerable. Alfalfa hay is more palatable than prairie hay, and in addition it has a toning effect upon the system of the cow.

ALFALFA FOR SHEEP AND HOGS.

It is not necessary to go into details in regard to the value of alfalfa for feeding sheep and hogs, as it would be largely a repetition of the preceding paragraphs. Experimenters and practical feeders find that alfalfa, when forming a portion of the ration, aids in making remarkable and economical gains.

Alfalfa is of great value as a hog feed, and alfalfa hay is practically the only hay that can be fed with decided profit to hogs. Naturally, the greater the leafage in the hay, the better adapted it is for hogs.

ALFALFA FOR POULTRY.

Alfalfa is of decided value for poultry. When fed to poultry the leaves alone are used, or if the hay is fed, it is used in the form of meal or chopped fine. One poultryman fed alfalfa to his capons. They were given the run of an alfalfa patch and later fed with chopped alfalfa and a little grain. Still later, alfalfa meal with a little wheat formed the ration, and finally steamed and cut alfalfa hay was added.

The profits are reported to have been very large. Alfalfa is of value in keeping poultry in good health. Alfalfa fed to hens stimulates egg production, thus forming a valuable winter feed.

ALFALFA IN THE ROTATION.

One common objection to alfalfa is that it does not fit well into the rotation. Alfalfa is likely to be such an important crop in North Dakota that this objection is liable to be overruled. The corn and alfalfa crops will develop together in great measure, corn taking the lead. It will generally be found advisable to have alfalfa follow corn. After four or five years in alfalfa, the land may be devoted to small grains for two or three years, and finally another crop of corn be planted.

But very few farmers would care to put their entire farm into a rotation of this kind. However, there is no reason that a limited portion should not be set aside for a rotation of this nature.

Before breaking an alfalfa sod it is generally best to get another piece established in alfalfa, for when once alfalfa has been used it is appreciated too highly not to have growing.

Whatever the rotation adopted by the farmer, there is no doubt but that the successful introduction of alfalfa culture upon the farm will produce very marked and favorable results. This rule has been without exception in all other districts.

EFFECTS OF ALFALFA UPON THE SOIL.

Alfalfa has a marked influence upon the physical character of the soil, as its root system is very different from the native grasses, or from the crops commonly cultivated. Its long tap roots bore into the ground to a depth of 8 or 10 feet or more, and form comparatively large channels in the soil. The fibrous roots of wheat, corn and grasses do not penetrate the soil much deeper than 4 feet, and the rootlets at that depth are so fine that no boring effects are brought about as is done with alfalfa.

Upon the death of the alfalfa plant the roots rapidly rot to such an extent that water is allowed to penetrate along channels where the roots were formerly found. The soil becomes more easily moistened than before, and the heavy rains can be taken care of with greater ease.

The rotting of the roots adds humus to the lower layers. The alfalfa roots feed to a depth of 8 feet or more, and bring up potash and phosphoric acid near the surface where it can be later utilized by other crops.

Theoretically, at least, the alfalfa plant adds humus to the upper layers of soil, and in many cases this has been found true, though, in other cases, a decrease of humus has been noticed with the growing of alfalfa.

Alfalfa tends to make heavy clay soils friable, and by the addition of humus and organic matter, light and sandy soils are rendered of better texture.

The Ontario experiment station found that alfalfa sod, after plowing, was more mellow and friable than any other sod in the test, including sods of red clover, alsike and timothy. Alfalfa increases the fertility of soils in a marked degree. At this same station, timothy sod and alfalfa sod were plowed and various crops grown upon the breaking. The trial was conducted during three years, with three different crops. The following is a summary of the results:

	1900 Winter Wheat bushels	1902 Barley bushels	1903 Corn bushels
Yield on alfalfa sod	61.5	30.2	24.0
Yield on timothy sod	42.1	19.7	17.9

This shows a remarkable increase in crops grown on alfalfa sod. Other experiments are as decisive as the one cited.

PLOWING ALFALFA SOD.

A well established field of alfalfa is difficult to plow, as the large tough tap roots are very resistant. Mr. J. E. Wing recommends that truck wheels be placed upon the beam of the plow, well forward, to hold the plow true. A knife attachment is often put on the landside of the plow, near the base of the share. This cuts into the next furrow, cutting off alfalfa roots that might otherwise remain. A 14-inch plow should be set to cut a furrow about 12 inches wide, as otherwise many of the roots are liable to slip by and not be cut.

Alfalfa sod should be plowed when moist, and a walking plow is generally preferred. Plenty of power must be supplied and the share must be kept sharp. A file will be of considerable value in this regard.

In Montana, under irrigation, the alfalfa is plowed shallow in the fall, and then in the spring, replowed to a greater depth. Mr. Wing finds that under Ohio conditions one plowing will kill the plants. Where alfalfa sod is plowed but once, there is considerable difference of opinion whether the breaking should be deep or shallow.

SEED PRODUCTION OF ALFALFA.

The climate of North Dakota generally will be favorable to the production of alfalfa seed. Where alfalfa can be grown, seed production seems to be more a matter of climate than of soil. Alfalfa sets seed most abundantly under rather dry conditions. If alfalfa is very rank, and supplied with an abundance of moisture, or if the atmosphere is moist, the flowers do not seem to become fertilized, and but little seed results.

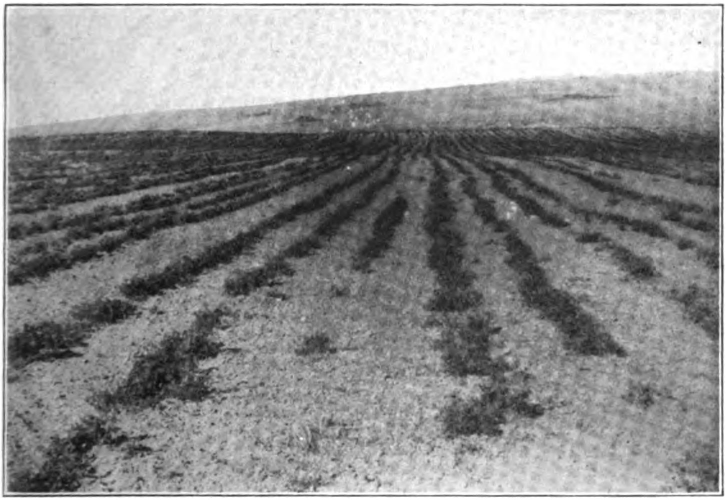


Fig. 4. A field of alfalfa in Montana, grown in cultivated rows for seed production. Photo taken after cutting. 1910.

Our knowledge of seed production in this state at the present time is very limited and no very definite statements it seems that alfalfa will produce the maximum amount of seed when grown in cultivated rows. At Dickinson, the second growth seems to produce seed more abundantly. When the stands are very thin, so that each plant may develop individually, and especially where some cultivation is given, then the first growth may set a full crop of seed. A yield of 5.6 bushels of seed per acre was secured at the Dickinson station in 1909 from alfalfa grown in cultivated rows. Fig. 4 shows a Montana field seeded to alfalfa in cultivated rows. There are a few cases in North Dakota where alfalfa has produced good yields of seed, grown under field conditions.

Beisigl Bros. of Stowers, N. Dak., state they threshed 40 bushels of seed, machine measure, from 10 acres. Mr. S. E. Kurtz of Hazelton, threshed alfalfa that made a little over 6 bushels of seed per acre. In both of these cases, evidently the second cutting was taken. Several farmers report alfalfa seed setting heavily in 1909; most of these reports were of small patches.

CUTTING AND THRESHING.

Alfalfa, for seed, should be cut when most of the pods are brown. A mower with a bunching attachment is well suited for cutting alfalfa for seed, and with this arrangement a man follows behind and lifts the alfalfa bunches to one side, to avoid trampling by the horses during the next round.

Alfalfa should be cocked, and, when well cured, threshed from the cocks. Alfalfa may be threshed in an ordinary threshing machine, if the smooth teeth of the concaves be replaced by corrugated teeth, manufactured expressly for threshing alfalfa.

At the Dickinson station, the concaves were filled with corrugated teeth and set well up to the cylinder. The machine was run rather slowly to avoid allowing the seed to be carried over. With these precautions evidently no seed was lost, and the work was done satisfactorily.

ALFALFA VARIETIES.

Turkestan alfalfa was introduced into the United States in 1898, and has been tried in various parts of North Dakota. The average Turkestan alfalfa is somewhat superior in hardiness to the average alfalfa grown in the United States. It may be somewhat more drouth resistant. It seems to make slower recovery after cutting than most alfalfas, and is decidedly inferior in seed production.

Most of the alfalfa that has been sown in the state is of the ordinary sort, similar to that grown in Kansas, Nebraska and Montana. Much of the seed has come from Montana. Montana seed seems to possess more hardiness than more southern grown seed.

Much mention is made of the value of dry land alfalfa, which is merely alfalfa seed produced under non-irrigated conditions. While this seed may be more valuable than seed grown under irrigation, there seems to be no experimental evidence to back up the popular notion.

GRIMM ALFALFA.

Grimm alfalfa originated in Carver County, Minnesota. The seed was brought from Baden, Germany, by Wendelin Grimm in 1857, and was grown by him for a comparatively long period. Grimm alfalfa was brought to the attention of the public by Prof. W. M. Hays of Minnesota, now Assistant Secretary of Agriculture, in 1903 and 1904.

This alfalfa possesses marked hardiness, and the variety as a whole seems somewhat drouth resistant. Grimm alfalfa is considered disease resistant, in Colorado. In North Dakota it is a few days earlier in flowering and in ripening seed. Its seed producing ability is good.

MEDICAGO FALCATA.

Much has been written in regard to another plant, **Medicago falcata**, or sickle lucern; also called yellow-flowered alfalfa. This plant is a native of Europe and Asia, and has been introduced into this country because of its supposed hardiness. Even granting hardiness, it is so deficient in other important characters that it can hardly hope to compete with **Medicago sativa.** The deficiencies of this plant have been pointed out in the third annual report of the Dickinson Sub-Experiment Station.

It may be of value in breeding work, or as a pasture plant. As is well known, many of the alfalfas contain a certain percentage of the blood of sickle lucern. Grimm alfalfa is quite strongly tinctured with **M. falcata** blood, and it is a question if it would be much improved by addition of more. There is an excellent field for scientific breeding along these lines, but nothing of value can be expected for a period of years.

RELATION OF ALFALFA TO LIME.

The production of alfalfa has an important relation to the amount of lime found in the soil. This has been particularly emphasized by Mr. J. E. Wing in his book, "Alfalfa in America." Alfalfa is a lime-loving plant and it does not thrive in soils that do not contain a reasonable amount of lime. One cannot fix the exact amount of lime that a soil should contain for success with alfalfa, as the character of the soil has much to do with the amount of lime necessary.

Because of the important relation between alfalfa production and lime content of soils it will be of value to give some analyses of North Dakota soils in regard to their lime content. Before doing this, a word in regard to our native flora will be in place.

The character of the native plants in any region is an indication whether the soil is limy or calcareous in nature. If the native flora contains a number of lime-loving plants, that alone is sufficient to indicate that the soil contains a reasonable amount of lime. The flora of North Dakota is characteristic in the abundance of lime-loving plants that it contains. This is expressed most strongly in the large number of species of legumes or plants belonging to the clover family. Other lime-loving plants that we have in abundance are the buck-brush, or wolf-berry, and the various kinds of sage.

A limy or calcareous soil is also indicated by the lack of certain species of plants which do not thrive with an abundance of lime. Such plants are the various species of the huckleberry and certain members of the heath family, which are not found in the state. A scarcity of sedges in North Dakota is also an indication of a sweet soil.

A compilation is given of the lime content of some of North Dakota's soils, taken from various analyses. The presence of lime is such an important factor, not only for the growth of alfalfa, but for other crops as well, that we may be pardoned for so many citations. The amount of lime is given in per cents. The analyses for soil is for the top 8 inches, and for the subsoil the second 8 inches. Analyses of many of the subsoils are lacking. The average of 0.97 per cent is for the top 8 inches of soil.

TABLE I.

PER CENTS OF LIME IN NORTH DAKOTA SOILS.

Place	Soil	Subsoil
Fargo	.78	
Fargo	1.19	
Fargo	2.17	6.23
Hillsboro	10.63	
Bathgate	1.32	
Barnes County	16.67	18.31
Minto	15.55	
Larimore	.60	
Lidgerwood	.62	
Lakota	2.38	
Lakota	.36	4.26
Langdon	.35	13.95
Jamestown	.14	.85
LaMoure	1.92	6.21
Rolla	1.64	
Bottineau	.55	
Devils Lake	2.49	
Devils Lake	25.76	
Ft. Totten	.94	
Leeds	.85	
Sykeston	.41	
Cando	.55	
Bismarck	.58	
Minot	.72	
Granville	.49	
Ross	.94	
New Salem	.58	
Dickinson	.32	Trace
Dickinson	.52	.58
Beach	1.70	

Average per cent of lime (omitting all above 5%) 0.97%.

In computing the average for the above table the localities having more than 5 per cent were omitted, as such seemed to be abnormally high and perhaps not characteristic of the region. The above figures indicate a rich lime content for North Dakota, according to the figures given by Prof. Hilgard, and Prof. Maercker of Halle. For sandy soils a lime content above 0.30 per cent is considered rich, and outside of the Red River Valley, most North Dakota soils contain considerable sand.

The soils at Dickinson do not show a very high percentage of lime, and in this connection it is worth while reporting that on the station farm, in nearly all cases where digging has gone down to a depth of 3 feet or more, the soil has been found very rich in lime; so rich that portions of it cause violent effervescence of acids.

The conclusion is that North Dakota soils are well stored with lime, and that as far as this point is concerned, and it is a very important one, alfalfa will thrive luxuriantly.

ENEMIES AND PESTS OF ALFALFA.

Alfalfa is attacked by a leaf spot disease which is manifest by the appearance of small black spots on the mature leaves. There are other diseases attacking the leaves of the plant. When these diseases begin to become injurious to the alfalfa it should be cut. The succeeding new growth will be less bothered. Certain stem and root diseases attack alfalfa, but their importance in North Dakota is unknown.

Perhaps the most serious enemy of alfalfa in this state at the present time is the pocket gopher. This rodent burrows in the alfalfa field, cutting off the roots, and in addition, throws up mounds of loose dirt. The mounds not only injure the alfalfa, but interfere with the cutting.

These pests may be poisoned by taking raisins, prunes or small pieces of potatoes, making an incision in the bait, and with the point of a knife, inserting a piece of strychnine half the size of a grain of wheat. These pieces are inserted in the runways of the gophers. The runway is located by a sharpened stick prodded into the ground. The bait can be dropped into the runway through the hole left by the stick. Trapping will serve to reduce their number.

THE PRESENT STATUS OF ALFALFA GROWING IN NORTH DAKOTA.

Letters with lists of questions were sent out to a number of North Dakota alfalfa growers, and a comparatively large number of answers were received. The trouble and care taken by those answering is very much appreciated. Enough complete reports were sent in so that tabulated results were made in 39 cases. Taking into consideration the average number of acres per grower, the method of handling the crop and the yields secured, we must consider that alfalfa growing in North Dakota is in its infancy.

There are evidently but very few men in the state that are handling the crop on a commercial basis. A few growers have learned the methods necessary for successful alfalfa culture.

Over the state generally the alfalfa is being grown in small patches, and but very few men have any considerable acreage. Fourteen of the 39 were growing an acre or less of the crop. Seven of the 39 were growing 10 acres or more. There were 17 of the 39 that had been growing the crop only 2 years, and only 6 men had been growing it more than 5 years.

Nineteen of the growers had put the crop in on upland, 13 in on bottom land, while the remainder had sown the alfalfa on land intermediate in character.

There were but 6 that had inoculated the soil or seed, while the remainder did not inoculate. This is a fact of importance, as practically all North Dakota soils need inoculation, especially upland soils. Fifteen men reported the alfalfa to be yellow and sickly looking, 14 as being dark green and vigorous, while 10 were indeterminate. This is a poor test to determine the presence of inoculation with those having no previous experience with the crop.

Twenty-nine seeded the crop broadcast. In 25 cases the alfalfa was seeded without a nurse crop.

Fifteen of the men reported no winter killing, but in several of these cases the crop has passed through but one winter which was comparatively mild. Five of those reporting stated that alfalfa killed from 1 to 10 per cent, and in 13 cases the alfalfa was reported as badly winter killed, in some cases completely. Six men made no report on winter killing.

Apparently in only a very few cases was the land prepared and the crop put in along the lines suggested in this bulletin. In spite of the fact that in many cases the alfalfa was given conditions that were unfavorable for its success, results were encouraging. Several of those reporting spoke of its having been sown too thickly for the best results.

Several spoke of its drouth resistant qualities during the dry season of 1910. In one exceptional case, Mr. John Kolkema of Mott, made 3 cuttings in 1910, totalling about 1½ tons per acre.

A FEW PUBLICATIONS DEALING WHOLLY OR IN PART WITH ALFALFA.

"Grimm Alfalfa and Its Utilization in the Northwest," by Charles J. Brand. Bulletin 209, Bureau of Plant Industry. Superintendent of Documents, Washington, D. C. 15 cents.

"Cold Resistance of Alfalfa," by Charles J. Brand and L. R. Waldron. Bulletin 185, Bureau of Plant Industry. Superintendent of Documents, Washington, D. C. 15 cents.

"Alfalfa in Cultivated Rows for Seed Production," by Charles J. Brand and J. M. Westgate. Circular 24, Bureau of Plant Industry. Secretary of Agriculture, Washington, D. C. Free.

"The Book of Alfalfa," by F. D. Coburn, Orange Judd Co., New York. $2.00.

"Irrigation of Alfalfa," by Samuel Fortier. Farmers' Bulletin No. 373. Secretary of Agriculture, Washington, D. C. Free.

"Alfalfa Hay vs. Timothy Hay for Dairy Cows," by W. J. Fraser and C. C. Hayden. Illinois Bulletin No. 146. Urbana, Illinois. Free.

"Alfalfa," by W. P. Headden. Colorado Bulletin No. 35. Fort Collins, Colo. Free.

"Troubles of Alfalfa in New York," by F. C. Stewart et al. New York State Station Bulletin No. 305. Geneva, N. Y. Free.

"Alfalfa," by A. M. TenEyck et al. Kansas Bulletin No. 155. Manhattan, Kas. Free.

"Alfalfa," by J. M. Westgate. Farmers' Bulletin No. 339. Secretary of Agriculture, Washington, D. C. Free.

"Alfalfa in America," by Joseph E. Wing. Sanders Publ. Co., Chicago. $2.00.

"Experiments in Clover Growing. Trials with Alfalfa," by J. H. Shepperd, North Dakota Bulletin No. 65. Agricultural College, North Dakota. Free.

PART II.

ALFALFA STUDIES MADE AT DICKINSON; PARTICULARLY REGARDING DROUTH RESISTANCE, WATER REQUIREMENTS AND SEED PRODUCTION.

By L. R. WALDRON.

AIM AND SUMMARY.

It will be the aim of this part of the bulletin to discuss in some detail the factors that go to make a proper stand of alfalfa when the crop is grown under the climatic conditions obtaining over much of North Dakota. The advice that has been given in regard to the proper amount of seed to sow under such conditions has generally been based upon experience gained under irrigation and in humid districts.

The evidence that has been obtained at Dickinson seems to indicate that successful alfalfa stands for ordinary North Dakota upland soils can be obtained when the rate of seeding is considerably less than usually recommended. The amount commonly recommended is 15 to 20 pounds of seed per acre.

It was found that a seeding as low as 10 pounds per acre apparently gave considerably too thick a stand for the maximum yield of hay.

Stands of alfalfa, much thinner than any supposedly normal stand, gave very satisfactory hay yields.

Studies of the root systems of plants from thick stands and from thin stands indicate that the plants from the thin stands have the very much better developed root system, which must explain, in part, the better yields.

The plant must grow a considerable amount of shoot to develop a good root, and for this, the stand may easily be too thick.

We may conclude that the thickness of alfalfa stands should vary, as the conditions approach or recede from the humid, either because of soil or of climate.

In all our studies good inoculation is found necessary.

Along with the thin stand, a certain amount of cultivation will be necessary to keep down the weeds, to loosen the earth to allow penetration of rains and to form a mulch to prevent undue escape of moisture from the soil.

Soil samplings in the thinner stands showed a greater amount of moisture in the soil than in the thicker stands. It was found that alfalfa grown in cultivated rows, yielding practically the same as when grown uncultivated in 6-inch drills, made a saving of 3.88 inches of water in 6 feet of soil.

Studies in seed production showed great variation in yields from different strains and from different plants. Seed production from alfalfa in cultivated rows and from field conditions are compared.

ALFALFA HAY YIELDS.

Practically the same alfalfa plats were cut in 1910 as were cut in 1909. The summarized yields of these are given in Table II. The first cutting yields of 1910 are considerably less than the corresponding yields of 1909. This fact is accounted for by the lessened rainfall of 1910. For most of the plats, the recovery after the first cutting in 1910 was so slight that no record was made of the yield. There was practically no second growth on most of the plats.

The first cutting in 1909 was made July 8, except the rotation plats, which were cut June 29. The second cutting was made August 5. The 1910 cutting was made June 20.

TABLE II.

ALFALFA HAY YIELDS, 1909-1910.*

Sown	Name or Source	S. P. I. No.	Height Inches	Per cent Bloom when cut	Yield per Acre—Lbs.		
					Crop of 1910	Crop of 1909 First cutting	Crop of 1909 Both cuttings
1907	Turkestan	14786	8-10	00	1216	2502	3042
1907	Simbirsk, Russia ..	13857	9-15	10	1052	2065	2579
1907	Utah	12784	10-14	2	580	1173	1591
1907	Colorado	12398	10-18	—	725	1131	1517
1908	Coml. Sand Lucern		12-18	10	1256	2136	2900
1908	Coml. Sand Lucern	21217	10-22	10	1071	1960	2611
1908	Coml. Sand Lucern	21269	8-22	10	1104	1603	2137
1908	Kansas	19508	11-18	2	377	1044	1372
1908	Canadian	21247	7-18	5	619	912	1244
1908	Grimm, Montana ..	21827	8-22	10	1102	1487	1741
1908	Grimm, Nebraska ..	21735	8-26	10	1178	1474	1857
1908	Turkestan	20988	8-20	2	951	1156	1377
1908	R. 42E (Grimm)			25	1802	3550	
1909	R. 42D (Grimm)			25	1291		
1908	Grimm (Rasche) ..		16-22	5	2756	4098	5262
		Sown in Rows.					
1908	Grimm		22-26	10	2855		
1909	Baltic		-29	100	2181		
1909	Medicago falcata....		-20	75	1868		

The above table is of little value in showing the comparative yields of the various strains. The differences in stand, root development, and inoculation are important enough to offset, in large measure, any differences that might exist between the different strains. Turkestan No. 14786 was cut earlier than others in 1910, so that its yield is not quite comparable with the other yields. The Utah. Colorado and Kansas plats had been badly winter killed, and the plants remaining had not assumed normal development.

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*The data presented in Part II were obtained at the Dickinson Sub-Experiment Station, Dickinson, North Dakota.

Mr. Charles H. Clark, Assistant in Agriculture, was instrumental in securing considerable of the data presented in Part II, and it is desired here to render thorough appreciation and acknowledgement of his valuable services. Mr. C. M. Hennis, student assistant in 1910, gave valuable and efficient help.

Several of the above plats were in charge of Mr. Charles J. Brand and Mr. J. M. Westgate of the United States Department of Agriculture, and their kindly and efficient aid is gratefully acknowledged. Thanks are due to Mr. John C. Thysell, Assistant Agriculturist, Department of Agriculture, for aid in moisture determinations and for other help. It is desired to acknowledge data from the cooperative rotation plats of the Bureau of Plant Industry.

The "Rasche" Grimm. with a 1910 yield of 2756 pounds per acre. was from a plat of 1¼ acres seeded by itself in a draw between hills. Here, inoculation of the plants is of the best, and the soil is fertile. The plat was disced and harrowed in the spring of 1910. The inoculation in the Canadian plat was only partial.

Yields were secured from 3 plats upon which alfalfa was grown in cultivated rows. The yield of the Grimm alfalfa from the plat in rows amounted to 2855 pounds of hay per acre for the first cutting. The yield of the Baltic alfalfa, similarly sown, was considerably less. but the Baltic rows were 3 feet apart. instead of 2½ feet, as in the Grimm. and the stand was a year younger. The second growths of the 2 plats were taken for seed. A good second cutting could have geen secured from these plats, and probably a fair third cutting.

The yields secured in 1910 from the alfalfa field plats sown in 6-inch drills are not encouraging, especially in view of the fact that the recovery in most of the plats amounted to so little. The average height of the alfalfa in the various plats at the end of July was 6 inches, and the vegetation was sparse.

YIELDS IN EARLIER YEARS.

The results secured in 1910 from the plats sown in 6-inch drills were not surprising in view of some of the results secured before 1909. In 1906, 20 small plats were sown to alfalfa broadcast, upon good soil that had been broken in 1905. The seed was inoculated with pure culture, but apparently was not successful. A good stand was secured in nearly all of the plats, and a comparatively small amount of winter killing resulted during the winter of 1906-1907 for many of the plats. The growth of the alfalfa upon these plats in 1907 amounted to very little indeed. The total height of the plants did not amount to more than 8 inches, and no cutting was made during the season. The rainfall for the year, up to August 1, was 10.33 inches. In this case, perhaps lack of inoculation was the prime cause of failure, though other factors must have entered. one of which was thickness of stand. The rate of sowing was 20 pounds of seed per acre. These plats were plowed in the fall of 1907.

PLATS SOWN IN 1907.

By reference to Table II, it is seen that 4 plats were sown in 1907. These were cut in 1908, and yields secured. The 1908 yields were as follows:

Source	S. P. I. No.	Yield per Acre—Lbs.
Turkestan	14786	1170
Simbirsk. Russia	13857	941
Utah	12784	888
Colorado	12398	1028

In 1908 as in 1910 there was not enough growth after the first cutting to allow a second cutting to be made. In this case, also, the lack of inoculation was an important factor in the non-success of the plats. The rate of seeding of these plats was about 15 pounds per acre.

STUDIES IN DROUTH RESISTANCE.

In 1909 some studies were undertaken to determine, among other things, the water requirements of alfalfa plants, the best thickness of stand to obtain maximum yields, and the effect of shading of the alfalfa plant upon the moisture and temperature of the ground. To aid in this work there were planted, at the instance of Mr. Charles J. Brand, 4 plats of alfalfa with Grimm plants one year old. The plats measured about 12x30 feet. In Plat 1 the plants were put in 8 inches each way; in Plat 2, 16 inches each way: in Plat 3; 24 inches each way, and in Plat 4, 36 inches each way. Planting was so arranged that there were 731, 189. 90 and 50 plants planted in the plats, respectively. The plat having the fewer plants was somewhat larger than the other plats.

A number of measurements were taken for height and weight to show the variation of plants in the plat. These are not of particular interest at this point and will not be discussed. The total yields secured from the 4 plats are important, as bearing upon the drouth resistance of the plant.

The criticism that may be made against the results is that the plats were too small to secure yields to make them comparable to field yields. This criticism would be hardly just, as the results obtained were not out of the ordinary and there is nothing to lead us to believe but that similar results could have been obtained, had the 4 plats each covered an acre or more in extent. The results are, in a way, ideal, but they suggest to us some very important ideas. The following table gives the yield of the three cuttings, in pounds of air-cured hay per acre, corrected as far as measurable errors are concerned. The principal correction was made necessary by the slightly unequal size of plats.

TABLE III.

ALFALFA YIELDS FROM DEFINITE DISTANCE TRANSPLANT PLATS. 1910.

Plat	Thickness of Planting	Stand,—Plants per square yard	Yields per Acre—Pounds Yield at Cuttings 1	2	3	Total cuttings 1 & 2	Yield cuttings 1, 2 & 3
1	8x8 inches	20.3	2296	933	494	3229	3723
2	16x16 inches	5.0	3026	1169	579	4195	4774
3	24x24 inches	2.3	2382	1180	612	3562	4174
4	36x36 inches	1.0	1888	944	632	2832	3464

The three cuttings were made June 24, July 22 and September 8. The entire amount of hay was secured, care being taken to lose none of the leaves. It is quite certain that in the first and second cuttings, the hay was drier than it would ordinarily have been, had it been cured and weighed under field conditions. The increased weight, due to the lack of loss of leaves, is thus partly offset by the decreased weight due to the drier weights of hay obtained.

STUDY OF TABLE THREE

For the first cutting, Plat 2, plants growing 16 inches apart each way, gave the greatest yield of cured hay per acre. Plats 3 and 1, with plants 24 and 8 inches apart each way, follow next in order with considerably lessened yields. Plat 4, with the plants 3 feet apart each way, gave the least yield.

It will be observed that these yields are not excessive. and, considering the season, one would at least expect equal yields from a successful alfalfa field.

Yields from the second cutting, made a month later, showed Plat 3, with plants 2 feet apart each way, to be in the lead with 1180 pounds of hay per acre. Plat 2, with plants 16 inches apart, has a yield nearly as large. Plats 1 and 4, having the thickest and thinnest plantings, have nearly the same yields, about 200 pounds per acre less than the other two plats.

The third cutting, made September 8, shows us that the maximum yield came from Plat 4, with plants growing 3 feet apart each way. Yields decrease in regular order from Plats 4 to 1, and in the latter plat we find less than ¼ of a ton of air-cured hay per acre.

A glance at the total yields from all of the cuttings indicates that Plat 2, with plants growing 16 inches apart each way, had the maximum yield of 4774 pounds of air-cured hay per acre. This yield is good, but not excessive, for those regions of somewhat limited rainfall where alfalfa is a staple crop. Doubtless it is more than is usually obtained upon North Dakota farms, where sub-irrigation does not enter in. The second highest total yield is from Plat 3, with plants 2 feet apart; the third is from Plat 1, with plants 8 inches apart, while the lowest total yield is from Plat 4, with the plants 3 feet apart.

It is desired to call attention to the stand of the four plats. Plats 1, plants 8 inches apart, has a fraction over 20 plants per square yard. The remainder of the plats follow with 5, 2 and 1 plant per square yard, respectively.

As the season advanced and as less moisture became available for the plants, the maximum yields were continually being shifted towards the plats having the thinnest planting. This is an interesting and an important fact.

YIELDS IN THE FIELD

Just adjoining the definite distance transplant plats, were 2 field plats of about one-half acre each, of Grimm alfalfa, sown in 1908. See Table II. One of the plats was from seed obtained from Montana (S. P. I. 21827) and the seed of the other plat came from Nebraska (S. P. I. 21735). The Montana plat was sown at the rate of 13.9 pounds of seed per acre. The inoculation of these 2 plats was not good for the first season, but they were inoculated the second season with alfalfa dirt, and examination made in the fall of 1910 showed an abundance of nodules upon the roots. In September, 1910, the thickness of stand was determined upon several representative square yards.

In the Nebraska Grimm plat, 156 plants per square yard were found, and in the Montana Grimm there were 167 plants per square yard. By referring to Table II, it will be seen that the Montana Grimm gave a yield of 1102 pounds of cured hay per acre, while the Nebraska Grimm yielded 1178 pounds per acre. As stated previously, the second growth from these Grimm plats, and indeed from nearly all the field plats listed in Table II, was so slight that yields were not obtained.

To render graphically the figures found in Table III, and those given for the Grimm plats, Chart 2 has been constructed. Squares have been drawn and these contain dots, each dot representing a plant. Each square represents a square yard. Vertical columns above the squares represent yields, each space standing for 500 pounds of cured hay per acre. For the 4 plats, where more than 1 cutting was made, the yield for each cutting is indicated, the first cutting being nearest the square.

The squares representing the two field plats are striking because of the number of dots they contain, as compared with the squares representing the definite distance transplant plats. As thick as the plants are in the field plats, they are by no means so thick as the original sowings might warrant.

Assuming 230,000 alfalfa seeds per pound, and it is claimed Grimm seed runs at about such a rate, a seeding of 15 pounds of seed per acre would provide for 713 plants per square yard. The actual seedings that the two Grimm field plats obtained was sufficient to give a stand of 661 and 485, plants per square yard, provided that all seeds would grow.

Thus, in the Montana Grimm plat, 25 per cent of the seeds that were sown grew and made plants that lasted through three summers and two winters. In the Nebraska Grimm plat, 32 per cent of the seeds made plants lasting through the same period. Assuming that Plat 2 of the transplant plats had the best stand for the maximum yield, the amount of seed per acre actually required to produce that stand, if all seeds grew and made plants, would be the absurdly small amount of less than 2 ounces of alfalfa seed per acre.

PLANTS PER SQUARE YARD.

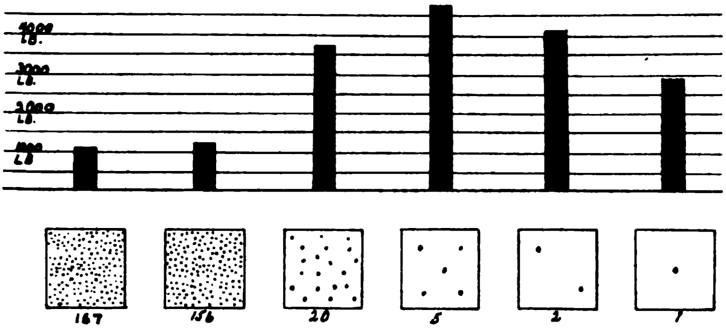

Chart. 2. Shows comparative yields of alfalfa from thick and thin stands. Each square represents a square yard, and the dots, the number of plants growing in such an area. The columns above the squares indicate the yields of air-cured hay per acre from the corresponding stands. For a fuller discussion of this, the reader is referred to the text.

From Chart 2 it is seen that the difference in yield between the field plats on the one hand and the definite distance transplant plats on the other, is very marked indeed. The two columns upon the left represent the yields for the field plats, while the four columns upon the right represent the yields for the other plats. This difference in yield was not brought by cultivation, for the soil of the transplant plats was left undisturbed during the season, or rather disturbed only enough to allow the weeds to be carefully removed. The soil was not hoed or cultivated.

The yield even from that plat having the thinnest planting, one plant per square yard, is seen to be much greater than the yield from either of the field plats. The fact of the matter is that the plants of the field plats did not develop at all normally, either below or above ground. A study of Fig. 5 will show this. These plants were taken from the Montana Grimm plat, in September, close to the transplant plats. It will be remembered that the Montana Grimm gave a yield of 1102 pounds of hay per acre. The roots of 3 of the 4 plants shown in the figure were so short that less than 3 feet of root could be dug out, even with considerable care.

Fig. 6 shows excellent root development of common alfalfa. This plant received no cultivation and grew part of the time in competition with western wheat grass. It was under ordinary conditions, with this difference, however, that it did not suffer by close competition with other alfalfa plants.

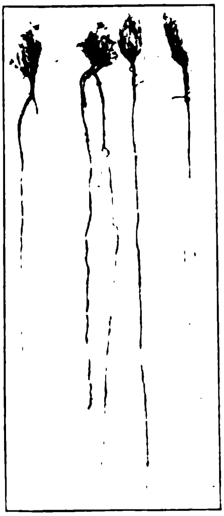

Fig. 5. Alfala plants taken from thick stand in field. Roots about 8 feet long.

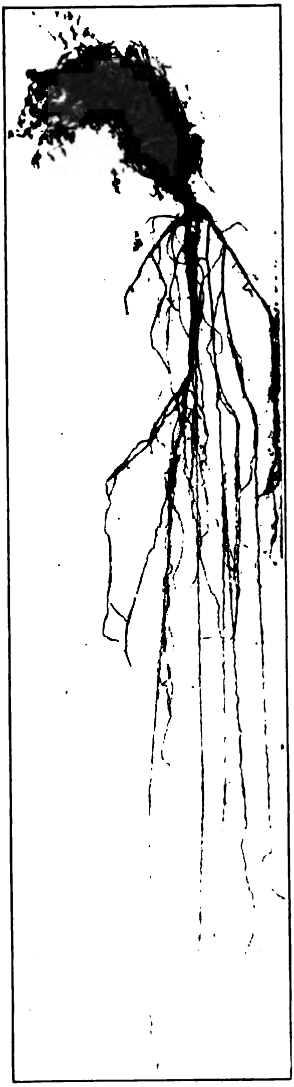

Fig. 6. Alfalfa plant from thin stand. Roots over 7 feet long.

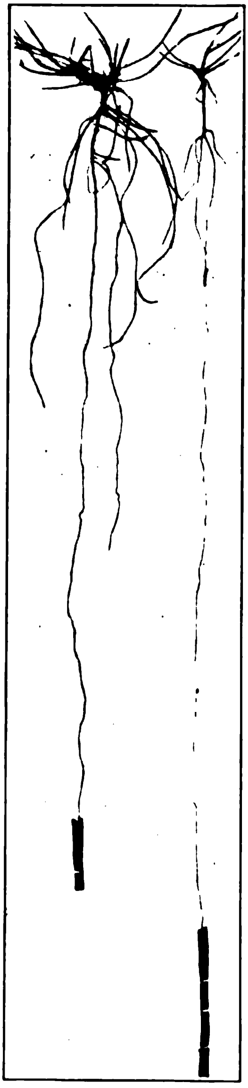

Fig. 7. Sickle lucern (Medicago falcata), sown in cultivated rows, 15 months from seed. Roots of small plant 8 feet long.

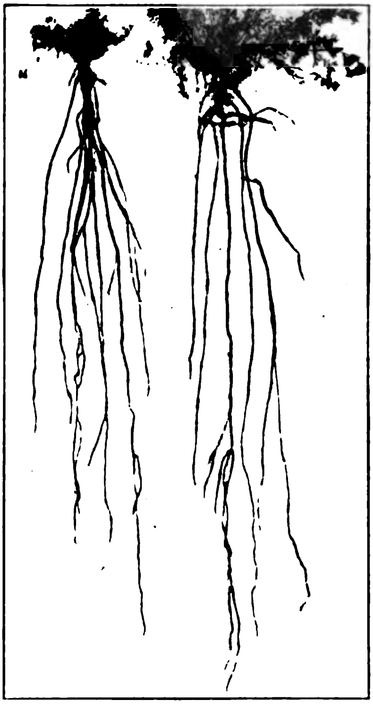

Fig. 8. Two transplanted plants, showing the effect of transplanting. (Figs. 5—8 and 11 engraved to same scale).

Fig. 7 shows two plants of the yellow-flowered alfalfa, (**Medicago falcata**). These were secured from plants growing in rows that had been sown 15 months. The roots of the smaller plant had obtained a length of 7 feet, 11½ inches. The diameter of the root at the crown was but 1-6 of an inch, while the diameter at its bottom was 1-25 of an inch.

CHARACTERS OF PLANTS IN THICK STANDS

A comparison of Figures 5 and 6 show that the plants obtained from the Grimm field plats are improperly developed. In Fig. 5 it is seen that only one of the plants has developed a normal tap root. The plant at the left used one of its lateral roots as a tap root. The plant next to it has two lateral roots acting as tap roots, while the real tap root is very poorly developed, and with the plant at the right, the tap root has divided, apparently at the bottom of the furrow slice.

Without more knowledge, it would be impossible to give the exact reasons for the poor development of the plants shown in Fig. 5. Lack of initial inoculation was probably a factor. However, good inoculation came on later. The main reason was undoubtedly the too thick stand,; at least for the amount of moisture available.

Under our somewhat dry conditions, we do not find a water table down at a depth of 8 or 10 feet, as is found in many humid districts. In dry farming regions the crop must depend upon moisture found in the upper few feet of the soil, except in cases of inter-tillage. There is found no stored moisture at depths of 5 to 15 feet upon which the plants may draw during the dry periods. When one makes a very thick planting of alfalfa, or of any crop, it is impossible for each plant to make its best development. There is not room enough above ground for the plant to produce its maximum leaf growth. Each plant becomes stunted to a greater or less extent, dependent largely upon the thickness of the planting. Root development goes along more or less evenly with the development of the stems and leaves. If the leaves and stems develop only slightly, we may expect a corresponding development of the root. Such an instance we find exhibited in Fig. 5.

Now in certain seasons of the year, the rainfall is in excess of that demanded by the plants. More water enters into the properly prepared soil than can be used at the time. The moisture penetrates into the deeper layers and we find that if the soil is not too compact or if the plants do not grow so closely together as to cause much run off, the moisture may penetrate to a depth of 6 to 10 feet, so that the layers of soil at that depth will be plainly moist or even "wet." Thus it must be apparent that an alfalfa plant that has developed a normal or rather an optimum root, as shown in Fig. 6, going down to a depth of perhaps 8 or 10 feet, can furnish a very much larger supply of water to the stems and leaves of the plant than roots of such plants as are shown in Fig. 5.

REASON OF GOOD YIELDS

So we seem to have a reasonable explanation why the yield of hay from the 4 transplant plats is so much greater than the yield from the 2 Grimm plats. The roots of the plants of the 4 plats that produced the good yields had a better development than the roots of the plants from the field. The roots of the transplant plants had better development, they went to a greater depth and they were enabled to draw upon greater supplies of moisture than the plants in the field which were so thickly planted.

However, we find a difference even among the 4 transplant plats. Plat 1, for instance, which had about 20 plants to the square yard, produced less hay per acre than Plat 2, which had only 5 plants per square yard. From this we naturally conclude that the plants planted even so thinly as 20 per square yard are still too thick, when growing under the conditions that they had in 1910. The roots had not attained optimum development, nor had they gone deeply enough into the ground to secure the maximum water supply.

The plants in Plats 3 and 4 had indeed reached at least nearly maximum development, but there was still room for other plants to develop and do well. It is apparent from the chart that when we have 5 plants per square yard, under the conditions of our experiment, we have something like the best development of each plant, and also the maximum thickness of planting. It is quite possible that a plat planted intermediate in thickness between Plats 1 and 2 would have shown even a greater total yield of hay.

The plants in the 4 transplant plats were scarcely normal, as they were transplanted plants, but the transplanted plants were probably no more able to secure moisture than plants not transplanted. A transplant plant from another plat was dug up and photographed. This is shown in Fig.

8. Here we see many roots acting as tap roots. These are rather small, though they aggregate a good size, but do not go down to a great depth. While the root system shows good water gathering powers, yet it is probably no better than is possessed by the roots of the plant shown in Fig. 6.

From a practical standpoint, the stands of the four transplant plats may not be desirable. They are of value in showing possibilities of improvement of the ordinary field stand under semi-arid conditions.

QUALITY OF HAY FROM DIFFERENT STANDS

The point might be raised that the hay from the thin stands would be of inferior quality because of its coarse and stemmy character. This could hardly be well taken, as all that it is aimed to do is to obtain growths in the thin stands comparable to those obtained in thicker stands under more humid conditions. It must be understood that this question of stand is merely a relative matter, and must be adjusted to suit local conditions.

Determinations of percentages of stems and leaves were carefully made for samples of hay from the third cutting, of three of the definite distance transplant plats. Results were as follows:

Thickness of planting	Per cent leaves	Per cent stems
8x 8 inches	56.7	43.3
24x24 inches	57.0	43.0
36x36 inches	53.4	46.6

The hay from the thinnest stand has a slightly higher weight of stems. The differences doubtless would have been greater for the first cutting. The above samples of hay may be considered very choice.

ALFALFA IN THE ROTATIONS

In the cooperative rotation plats, one of the rotations has alfalfa for one of the crops. Alfalfa is sown one year and the stubble is plowed the second year after, so that the alfalfa has three seasons' growth. The rate of seeding has been 15 pounds per acre. Excellent stands have been secured. Plat 42D, sown in 1909 with the Grimm seed, gave a yield in 1910 of less than 1300 pounds of hay per acre at the first cutting. This plat had a thick stand of 337 plants per square yard. There was no second cutting, as the alfalfa made absolutely no recovery, or at most the second growth did not amount to more than one or two inches.

This was not true along the edge of the plat, however, where the recovery was excellent. At this point, alfalfa grew up to a height of 18 to 24 inches and formed a seed crop. If this edge had been cut at the proper time a very fair third growth would have been made. Plants from this plat could not be dug, but we can have no doubt that if they had been, we would have found the plants that made no recovery had the root systems similar to the plants shown in Fig. 5, and that the plants from the edge, that made good recovery, would have had root systems approaching that of the plant shown in Fig. 6.

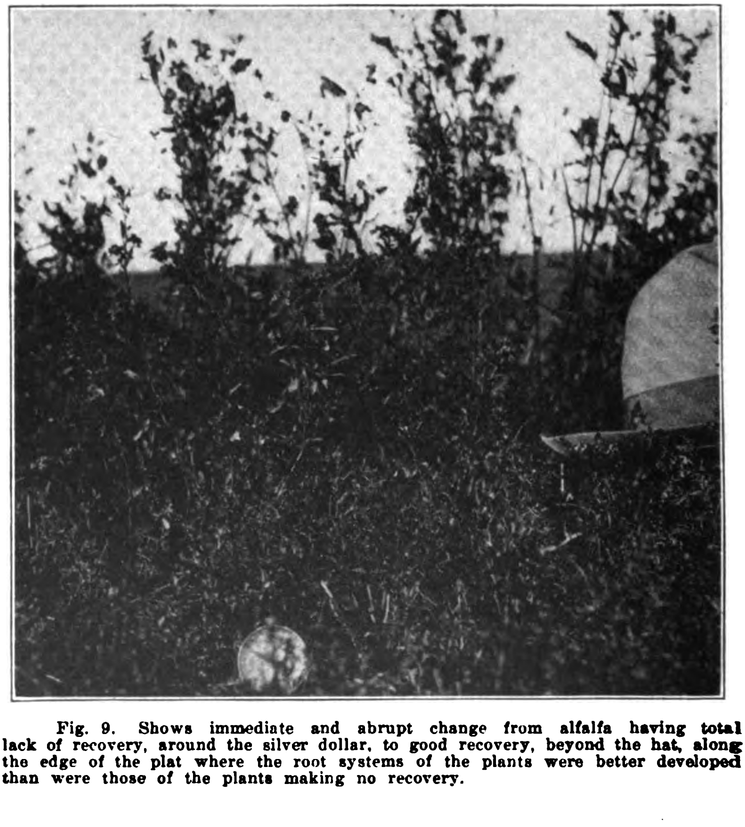

Fig. 9. Shows immediate and abrupt change from alfalfa having total lack of recovery, around the silver dollar, to good recovery, beyond the hat, along the edge of the plat where the root systems of the plants were better developed than were those of the plants making no recovery.

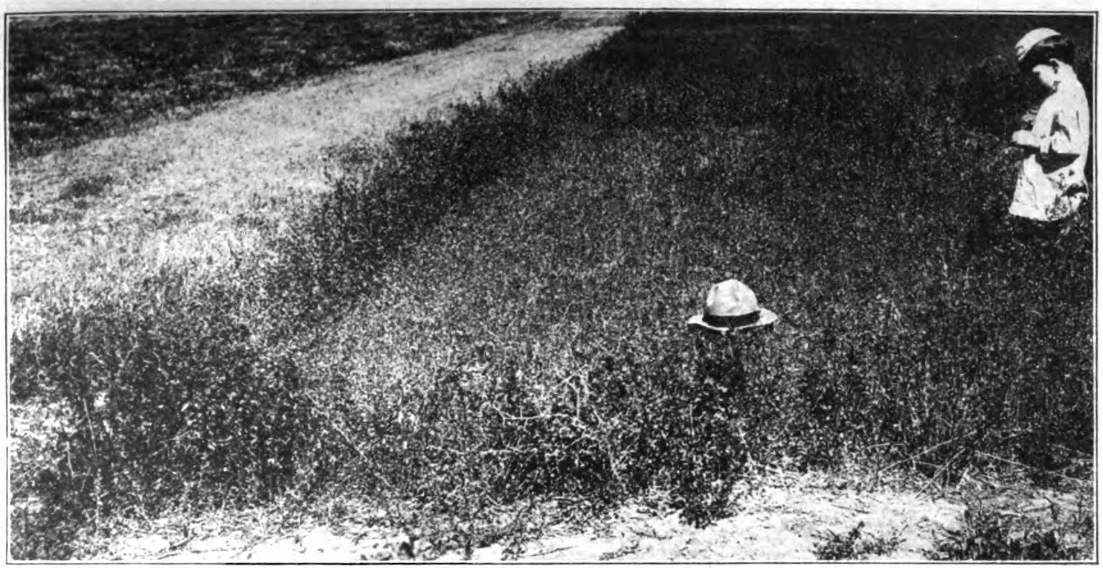

Fig. 10. Shows "dished" effect of square rod plat. The edge made a good second growth and seeded. No second growth in the interior. Plants from this plat shown in Fig. 11.

In Fig. 9, is seen the extreme and abrupt transition from no recovery to good recovery on Plat 42D within the space of a foot. Around the silver dollar the alfalfa made almost absolutely no recovery, at the time the picture was taken on September 13, since the first cutting, 92 days previous, on June 23. Beyond the hat, the edge made good recovery and considerable seed was formed. A third growth would have come on had the edge been cut at beginning of second bloom.

"DISHED" EFFECT IN SQUARE ROD PLATS

A number of square rod plats were sown broadcast to alfalfa in 1909, at the rate of 15 pounds of seed per acre. A very fair yield of hay was secured from these in 1910 at the first cutting. The second cutting was not made. Except on the edges of the plats, the alfalfa made essentially no growth after the first cutting. Fig. 10 shows one of these plats, sown from Montana seed. The plat was cut July 1, and the photo was taken September 20, 82 days after cutting.

All the central area upon which lies the hat, made very little or no growth after cutting. The edge of the plat in which the boy stands, made very good growth and if it had been cut at beginning of second bloom, a third growth would have been produced.

Here again there is a difference in the roots of the plants in the central portion of the plat and at the edge. The root systems of the plants at the edge are fairly large and well developed, and they draw their water from the deeper layers of the soil. The plants in the interior of the plat have stunted roots.

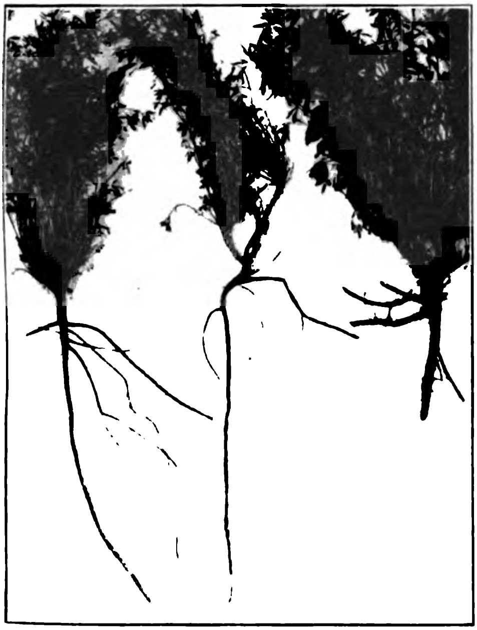

Fig. 13. Alfalfa plants plowed under three years previous to digging. Roots mutilated in digging.

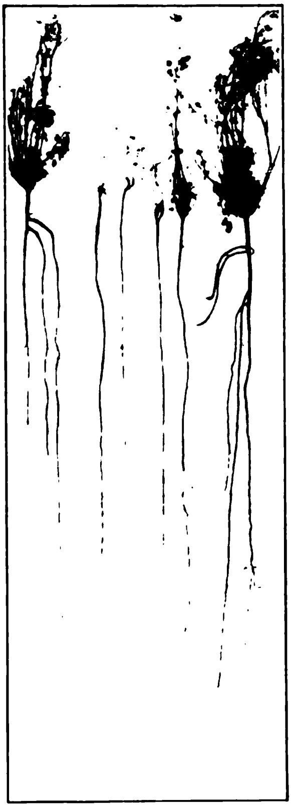

Fig. 11. Alfalfa plants from edge and interior of thickly planted plat. These plants from plat shown in Fig. 10.

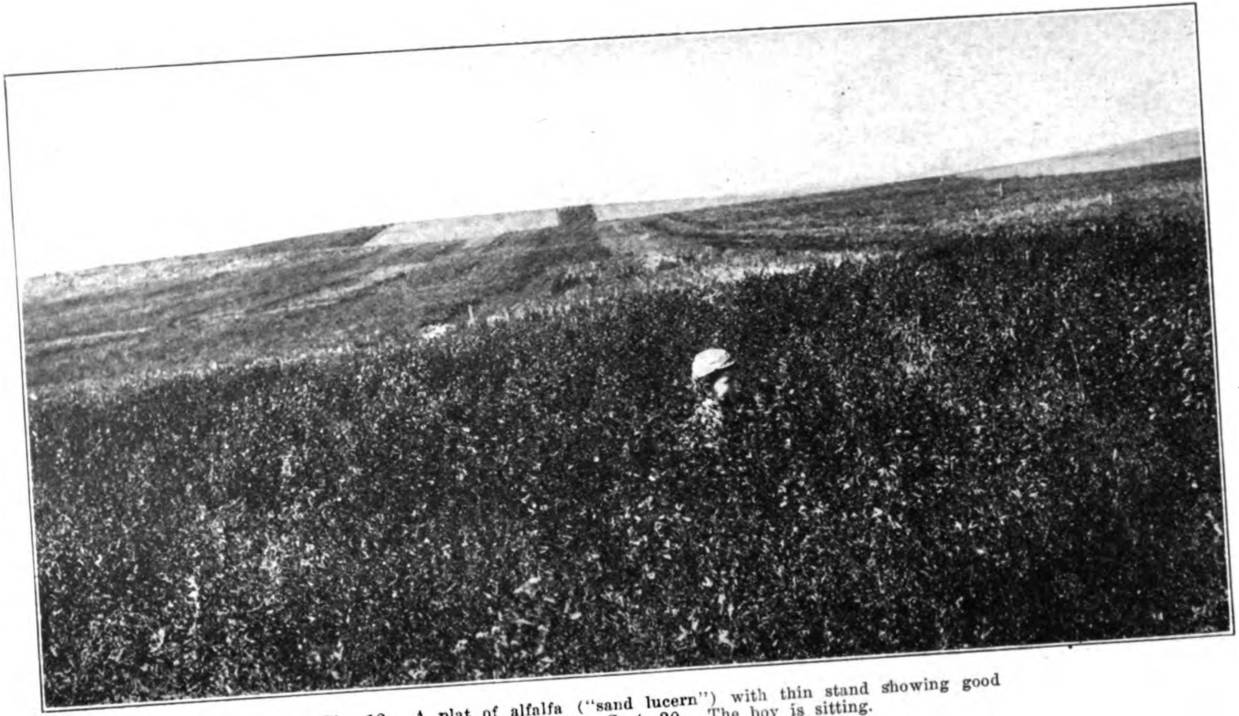

Fig. 12. A plat of alfalfa ("sand lucern") with thin stand showing good third growth for 1910. Photo taken Sept. 20. The boy is sitting.

While our other studies made this fact fairly certain, a few characteristic plants were dug and photographed. These are shown in Fig. 11. The plant at the right and at the left came from the edge. The second and third plants from the left were taken from the center of the plat. The two next in order came from the inner edge of the outside strip.

The plants grew so thickly that something resembling a sod was formed, and the water doubtless penetrated less readily than where more open planting is practiced. The roots being stunted, did not penetrate into the ground far enough to draw upon the supplies of moisture stored there in times of heavy periods of rain It is not impossible that lack of early inoculation of the plants in the center of the square rod plats had something to do with the proper development of the plants. However, the inoculation was the same over the whole plat, though along the edge, there was doubtless more nitrogen available for the plants.

GENERAL STATEMENTS

The presence of an extensive root system is very material in soils having limited stores of moisture, as under semi-arid conditions. Such a root system cannot be developed without a proper growth of the shoot, which is prevented by too thick a stand. A short and undeveloped root is mechanically unable to secure moisture from the lower depths, stored in periods of heavy rains. Other things being favorable, three things are quite essential; enough space for the proper development of the shoot, enough space and moisture for the proper development of the root, and a proper initial inoculation of the plant.

GOOD GROWTH IN OPEN PLANTING

We have certain pieces of alfalfa on the sub-station farm, which, by accident or otherwise, have thin stands. A portion of one of these plats is shown in Fig. 12. The seed was secured of Currie Bros. as "sand lucern." It was sown at the same time as the two Grimm plats which have been discussed in connection with the transplant plats. The entire plat received good inoculation at the time of sowing. That portion of the plat shown in the figure has a thin stand. The photo was taken September 20, 1910.

This plat was cut June 20, and after cutting, a fair second growth was made which was cut July 25. After the second cutting, the alfalfa made a third growth and on September 20 it was in blossom and had attained a height of 17 to 19 inches. As it stood it would probably have made a yield of 600 pounds per acre. While good inoculation helped to make these plants vigorous, yet the thinness of stand which allowed normal plant development was undoubtedly the deciding factor which made this plat of alfalfa so much more successful than the two Grimm plats, previously described.

SELF-SEEDED ALFALFA

Some Grimm alfalfa was seeded in 1905. This was not part of any experiment and it has not received any especial care. As a consequence, seed formed which fell to the ground and germinated adjacent to the plat, forming small self-seeded areas of alfalfa, with thin stands. This alfalfa has received no care and has had to fight its way in competition with western wheat grass, which is closely related to quack grass. This self-seeded alfalfa has been very successful. During 1910 it was cut twice and made a third growth of 12 to 22 inches, when a photograph was taken.

ALFALFA PLOWED UNDER

Mention was made on page 394 of some small alfalfa plats sown in 1906 which were plowed under in the fall of 1907, as they were evident failures, the alfalfa not having made any appreciable growth during the second season. Although we thought the land well plowed, the spring of 1908 showed many alfalfa plants coming up. We did not realize the importance of leaving a definite portion, but the area was put into various crops. However, one strip immediately west of a strawberry bed happened to be left, though doubtless some efforts were made to eradicate these plants. Be that as it may, a number of them persisted and notes were taken of their behaviour during 1910. This area was cut twice during the season, and by the latter part of September a good third growth had bloomed and had attained a height of 15 to 20 inches. This was in spite of the fact that the plants were growing along with western wheat grass. The plants received no cultivation during 1910.

GENERAL STATEMENTS

The substance of the whole matter is that with the climatic and soil conditions that obtain at Dickinson, where our work was done, alfalfa must be grown in thin stands to secure successful results. There seems to be no sort of doubt but that the plants in a stand, normally secured from seeding at the rate of 15 pounds per acre, which has been generally recommended, are much too thick for the maximum hay crop with the rainfall that we have. This seeding may be suitable for irrigated regions, for the humid districts, or perhaps for regions of cold winters where hardy seed is not available and where a thin stand is sure to ensue after one or two winters. We may be sure that alfalfa culture will be considered a partial failure in this state generally, if we continue to sow our upland areas as heavily as is commonly recommended. I am presuming now on the use of hardy seed.

It will be a question how best to secure a stand of alfalfa thin enough to obtain maximum hay yields. It is possible to sow alfalfa seed more thinly than has been the custom. In one of our 1910 plats, alfalfa was sown as thinly as 5 pounds per acre, and as even a distribution was secured as when it was sown 16 pounds per acre. This seeding was done in May in 6 inch drills and a count the last of September showed on an average, 74 plants per square yard. Probably this is too thick a stand to secure the best final results, but Nature may reduce this to some extent, and discing may bring about still more reduction.

It is probable that after the first season, weeds would not interfere any more, or as much, in a thin as in a thick stand, for in a thinner stand the plants grow much more luxuriantly and are much better able to fight the weeds than when grown in close stands. As a matter of fact the alfalfa plant is a desert-like plant and does best when by itself. Then it has a chance to develop its wonderful root system which reaches deep into the earth after water, enabling a remarkable growth of top to take place, even though it is cut back two or three times during a season.

THINNING ALFALFA BY PLOWING

Plowing under a stand of alfalfa, abnormally thick, may be an excellent means of reducing it to a proper condition.

If alfalfa sod is properly plowed, and handled rightly, the plants are practically all killed, but one soon finds that it is easier to leave a few live plants than it is to kill them all. We plowed under a plat of alfalfa (Plat 42E) early in July 1910, that was seeded in 1908. The stand of the plat was too thick, being somewhat similar to that shown in Fig. 10. After plowing, a portion of this alfalfa came up, resulting in a much more satisfactory stand, as far as possible hay production was concerned, than existed before the plowing. The alfalfa made considerable growth after plowing. A plat of alfalfa beside it, sown under similar conditions, made no growth during the same time, with the exception of the plants growing around the edges of the plat. The growth in the plowed plat was due to the rains of July penetrating the plowed soil more easily than the hard and compact soil of the unplowed plat.

The plowing under of the plants does not seem to have injurious influence upon the normal root development. Three plants are shown in Fig. 13, dug in the fall of 1910. Seeding was done in 1906 and the plants plowed under in the fall of 1907. The plants were from the fortieth acre plats discussed on page 394, which were a failure. The two plants at the right have the crowns divided, evidently due to plowing. The plant to the left appears quite normal. The dividing of the crown might be of real advantage.

In the fall of 1907, after two years' growth, these plants had not obtained a height of more than 8 inches and there seemed to be no future hope for them. The alfalfa was a failure. But after the plat was plowed, the plants rejuvenated, developing large crowns, and deep, extensive root systems. One of these plants was dug and the root system photographed. The photo shows a remarkably developed root system with a length, as dug, of 7.2 feet. See Fig. 6.

SOWING IN ROWS

Another method of securing a thin stand would be to sow the alfalfa in rows, wide enough apart to admit of more or less cultivation. While we have carried on some of this work, it is not known positively if the extra labor involved by this method brings about a profitable increase of crop. After cutting the field sown in rows, it may be disced and harrowed as though it had been sown broadcast or in 6-inch drills.

Various other methods of seeding suggest themselves. The alfalfa may be sown in 12 or 18 inch rows, and rather thinly in the row. This method may be better either than if sown in 6-inch drills or if sown in rows wide enough to be row cultivated. It might be well to sow 3 or 4, 6-inch drills side by side and with enough space allowed between the two adjacent sown strips of alfalfa for cultivation.

It is feared that the idea of sowing 12 or 15 pounds of seed per acre, in 6-inch drills, has become too well grounded in the minds of the farmers of the state. However, to cling to such an idea, merely because we have it, is something of a superstition. The erroneous idea of thick seeding is fostered by writers of the agricultural press who have obtained their knowledge from books rather than from experience.

SOIL MOISTURE IN RELATION TO ALFALFA GROWTH

Considerable soil sampling was done on the alfalfa plats during the season of 1910, and while the work must be carried out several seasons for definite conclusions, the results are of some interest. In practically all cases, a vigorous growth of plants was associated with good moisture content, and vice versa. As would be expected, the sandier soils dried out much rapidly than the heavier soils, and upon such soils the alfalfa growth was comparatively deficient. In some cases, a layer of sand was underlaid by a layer of clay. Clay retained the moisture, so the sand above was somewhat moist. The sand immediately underneath the layer of clay would also often be moist, due to the percolating effect of the water from the clay.

About the middle of September some soil samples were taken from alfalfa under various conditions, and results are given herewith. The first sample was taken to a depth of 18 feet, on a plat of sickle lucern (**M. falcata**), grown in cultivated rows, not yet cut at time of sampling.

The second sample was taken from a plat of alfalfa sown broadcast in 1906, plowed under in the fall of 1907, and which volunteered to make a good stand. Two cuttings had been removed in 1910, and the alfalfa, at time of sampling, had grown to a height of 20 inches.

The third sample was from the plat of No. 21827, Grimm alfalfa, sown in 6-inch drills in 1908. The plat was cut but once during the season, yielding 1102 pounds of hay per acre. The fourth sample was from virgin prairie.

TABLE IV

SOIL MOISTURE FROM ALFALFA SOIL SAMPLES

IN PER CENTS OF DRY WEIGHT

Depth in Feet	Sample No. 1	2	3	4
1	6.6	12.0	7.5	11.0
2	5.7	10.5	11.1	11.6
3	6.1	10.2	14.9	11.7
4	6.8	8.8	7.1	9.3
5	11.4	9.4	7.6	9.3
6	5.8	9.7	7.6	9.8
7	8.6	13.3	9.3	10.7
8	11.6	14.4	10.8	11.4
9	8.7	23.6	15.7	12.2
10	26.6	20.7	15.3	6.6
11	30.6	27.7		6.4
12	14.4	9.4		6.6
13	8.3	10.4		
14	10.0	8.6		
15	8.9	6.5		
16	8.8	6.4		
17	8.7			
18	8.6			

The character of the soil differs so, from foot to foot, that the mere expression of the amount of moisture may not be of much significance. In the 10th and 11th feet of sample 1, the soil was of a clayey consistency, and contained much moisture. The samples from the 13th to the 18th foot were of coarse sand, and were apparently as moist as the 10th and 11th foot samples. The larger soil particles did not allow as much moisture to be contained in the sample. The lower few feet of this sample were moist enough to sustain growth, although the percentage of moisture was quite low.*

The upper few feet of sample 2 were apparently dry, in fact, too dry to sustain growth. The soil was not palpably moist until the 7th foot, which condition continued until the 11th foot. From the 12th to the 16th foot the soil became drier and lighter in texture. The high percentage of moisture in the 9th, 10th and 11th feet is associated with the heavy texture of the soil. This soil has a thin stand of alfalfa, made two cuttings during the season, and at time of sampling the growth was, as stated, 20 inches tall. An alfalfa plant, (See Fig. 6), was dug out near where the sample was taken, its roots extending to a depth greater than 7 feet. Unless the root system had been well developed, a stunted growth would have resulted, similar to that found where sample 3 was secured.

---

*Before the land was broken, in 1905, where sample 1 was taken, one may assert with confidence that the soil was "dry" to a depth of 30 feet or more.

The soil from sample 3 was comparatively heavy. Moisture increased in amount at depths of 9 and 10 feet, where the sampling ceased. The alfalfa plants shown in Fig. 5 were taken from near where sample 3 was secured. The roots did not penetrate to a much greater depth than 3 or 4 feet. The lack of stem growth may be associated with paucity of root system, and with dryness of soil. The dryness of soil may be associated, at least in part, with thickness of the stand, and in part with lack of cultivation given the alfalfa.

The 1st and 2nd feet of sample 4, which was secured from virgin prairie, were apparently very dry, but as the soil was a clay loam, there was more moisture in this than in the lower samplings of sample 1. Despite the fact of 11 or 12 per cent moisture in the upper 2 feet of sample 4, no growth could have taken place. In fact, the entire sample was "dry" except the 9th foot. The soil at this depth had some palpable moisture.

The dryness of this sample we may generally associate with the character of the prairie vegetation, which is so dense that it forms, more or less, a waterproof covering to the lower soil layers. The water does not have a chance to penetrate into the soil, and consequently a small amount of growth results.

GENERAL STATEMENTS

We may say generally that moisture is more abundant in the soil where the alfalfa grew in cultivated rows, or where the stand was thin. In the soil having a thick stand of alfalfa, the moisture was so depleted that growth could not take place, the growth of the plants being further hampered by the diminished root system. The roots from this area are shown in Fig. 5. The soil sample secured from the thick stand of alfalfa more nearly resembled that from the virgin prairie than from the thin alfalfa stand, or from the alfalfa grown in cultivated rows.

USE OF WATER BY ALFALFA IN CULTIVATED ROWS

Comparative moisture determinations were made upon two plats during the season of 1910. These two plats were sown the same time in 1908, with Grimm alfalfa. Plat 16 was sown in rows 30 inches apart, and what we call the valley plat, was sown in 6-inch drills. About 15 pounds of seed per acre were sown in the valley plat, and about 3 pounds per acre were sown in Plat 16. The plats were not adjacent. The valley plat has some slope, while Plat 16 is nearly level. The yielding capacity of the valley plat is equal, or superior, to that of Plat 16. Differences connected with the two plats are probably not such as to injure our results.

Moisture determinations were taken upon these two plats April 1, before much of any growth, and again on June 24, at time of cutting. The percentage of moisture in the two plats for the upper 6 feet are as follows:

TABLE V

MOISTURE IN ALFALFA PLATS

Date Sampled	Depth in Feet						Average per cent.
	Valley Plat (uncultivated, 6-inch drills)						
	1	2	3	4	5	6	
April 1	30.2	19.6	15.1	12.4	10.7	12.1	16.68
June 24	12.2	9.6	8.8	8.9	9.4	8.2	9.52
						Diff.	7.16
	Plat 16 (cultivated, 30-inch rows)						
April 1	26.2	19.4	12.9	12.8	11.3	10.1	15.45
June 24	15.5	15.3	14.1	11.8	10.7	8.8	12.70
						Diff.	2.75

The rainfall is assumed to have been the same on both plats, and amounted to 5.58 inches. This included the lighter showers, some of which were of no particular value to the crop. The yield of hay per acre from the valley plat amounted to 2756 pounds, and from Plat 16, to 2855 pounds. The actual dry weight was not determined, but, assuming 20 per cent water in the cured hay, then we would have 2205 pounds of dry material per acre from the valley plat, and 2284 pounds of dry material per acre from Plat 16.

Adding the precipitation as pounds of water per acre to the difference of the moisture found in the soil at the two samplings, we obtain the water used by the crop, and also that lost by evaporation, surface and under-drainage. In the case of the valley plat we find that the total loss was at the rate of 1,348 tons of water per acre. On Plat 16 the total water loss was at the rate of 908 tons per acre. Dividing these amounts by the number of pounds of dry material per acre, we find that while it took 1248.6 pounds of water for each pound of dry matter from the valley plat, it took but 839.7 pounds of water for each pound of dry matter grown in Plat 16. This may be expressed as follows.

	Tons water lost per Acre	Yield dry matter	Water used for each lb. of dry matter	Acre-in. water for each ton of hay
Valley Plat	1,348	2205	1222.3	8.6
Plat 16	908	2284	794.7	5.6

SAVING OF MOISTURE

It is seen from Table V that the valley plat was more moist than Plat 16 at the beginning of the season. The valley plat lost 4.41 per cent more moisture during the season than Plat 16, for the upper 6 feet of soil. Translated to inches of rainfall, this means a saving of 3.88 inches. Plat 16 outyielded the valley plat only 100 pounds of hay per acre at the first cutting, but for the second growth, Plat 16 was remarkably better.

Prof. King found that the clover plant required 5.089 acre-inches of water for each ton of dry matter produced. That required by alfalfa is probably not much different. Results secured from Plat 16 agree very well with the figures secured by Prof. King. In our work, corrections were not made for percolation, run-off, or light showers, which were of no consequence to the crop.

The alfalfa plant requires more moisture than the wheat plant for each pound of dry matter produced. Prof. King, gives 4 acre-inches of water, in round numbers, for each ton of wheat crop. Compared with our results, this is a difference of 1.6 inches, in favor of the wheat, when the alfalfa was grown in cultivated rows.

Put in another way, the amount of water that would produce 2 tons of alfalfa, should produce a crop of wheat yielding 37.3 bushels per acre; but the alfalfa plant has an immense advantage over the wheat plant in that the amount of growth produced is not limited by the period of the plant's development. The wheat plant must have moisture available within certain limited periods in order to produce good results. With alfalfa, growth goes forward at any time during the season, if moisture and temperature conditions are favorable. Thus, alfalfa has been called "everlasting."

ALFALFA SEED PRODUCTION

Some studies have been made regarding the production of alfalfa seed. The outlook for this industry is encouraging, but much remains to be learned, both practically and theoretically. The nursery planted in 1908 contained something like 1000 plants in 1909. The amount of seed and the average yield of seed per plant, was obtained for each strain. The number of plants, the weight of seed in grams, and the average weight of seed per plant in grams, are given below:

Kinds	Number of Plants	Weight of Seed-grams	Weight of Seed per Plant-grams
Turkestan	264	3598	13.6
Other than Turkestan	754	16630	22.0
Selfed plants	19	276	14.5
Total	1018	20228	19.9

A total of 264 Turkestan plants gave an average yield of 13.6 grams, or nearly half an ounce. There were 754 plants other than Turkestan, which gave an average yield per plant of 22 grams, or about ¾ of an ounce. Nineteen caged plants, hand pollinated, gave an average yield of 14.5 grams. The total 1018 plants gave an average yield of 19.9 grams of seed per plant. These yields are quite high, as may be seen if extended to an acre basis. With plants 2½ feet apart each way, and with ¾ of an ounce of seed per plant, the yield per acre would amount to 327 pounds, or nearly 5½ bushels, which is a heavy yield for alfalfa.

VARIATION IN STRAINS

Some strains are remarkably better than others. The following summary includes some of the more striking variations:

Strain	No. of Plants	Seed per Plant grams
Baltic	45	42.5
Chinook, Montana (12816)	19	35.5
Commercial Sand Lucern (21269)	8	56.0
Grimm (2 strains)	123	21.9
South Dakota-Turkestan (32520)	59	8.8

COMPARATIVE SEED YIELDS

Plat 16 was sown to Grimm alfalfa in 30-inch rows in 1908. This plat produced a heavy crop of seed in 1909. In 1910 the plat was divided into two parts, A and B. The first growth of Part A was left for seed, while the first growth of Part B was cut for hay and the second growth left for seed. The yields from the two parts were not determined, but inspection show a good yield of seed from the second growth, Part B, while the seed crop on Part A was practically a failure.

The Grimm rows of the 1908 nursery were threshed in 1910. The plants grew a foot or more apart in the row. The yield of seed secured at the first growth was at the rate of 130 pounds per acre. From these results it would appear that had the plants in Plat 16 been much thinner in the row, —the plants in the row were comparatively thick,—the first growth, or Part A, would have made good seed production, as the conditions in Plat 16 and in the 1908 nursery were otherwise much the same.

Some alfalfa was sown late in July, 1909, in 3-foot rows. This was cultivated some in 1910, and the first growth was allowed to go to seed. The yield was at the rate of 109 pounds of seed per acre. The plants were much thinner in the row than in Plat 16, but thicker than in the 1908 nursery.

The second crop of the valley plat was left for seed. This plat is sown in 6-inch drills. The second growth was light on this plat, and the yield of seed amounted to but 16 pounds of seed per acre. A strip of the first growth of this plat was left for seed production, but only a very small amount of seed was formed. Moisture evidently plays a most important part in the formation of seed, and seed formation may be considerably influenced by the available nitrogen.

EFFECTS OF INSECTS

Four plants, adjacent to each other, were caged and under cage 1 were placed a number of bumblebees, under cage 2 a number of wild bees and wasps, under cage 3 a number of moths and butterflies, and the plant under cage 4 was left as a check. At the end of 24 hours, countings were made under cages 1 and 2. Under cage 1, 83 per cent of the 437 flowers in bloom were found to be tripped. Under cage 2, 91 per cent of the 267 flowers in bloom were found to be tripped. After a period of 60 hours, no flowers were found tripped from the total of 250, under cage 3. No flowers were found tripped under the control cage.

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NORTH DAKOTA
AGRICULTURAL COLLEGE

GOVERNMENT AGRICULTURAL
EXPERIMENT STATION
OF
NORTH DAKOTA

BULLETIN NO. 96

SOME PRINCIPLES OF DRY FARMING

BY

L. R. WALDRON

Any farmer, teacher, or student in the State may have this Bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
JANUARY, 1912

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SOME PRINCIPLES OF DRY FARMING *

BY L. R. WALDRON.

In understanding the principles that have to do with practices of moisture conservation it is necessary to have a few definite ideas regarding the soil.

STRUCTURE OF SOIL.

In the first place, the soil contains life in comparative abundance; bacteria, yeasts, molds and other fungi form a part of the soil life. In addition, there is found dead and decaying organic matter derived from roots, sticks, leaves, etc. Again we have humus which has been derived from organic matter like that mentioned. Soils rich in humus are known by their blackish color when wetted. Humus has a strongly modifying effect upon the water-holding power of a soil and also upon the tilth of the soil.

The greatest bulk of the soil is composed of mineral grains of different kinds and of different sizes. While the kinds of minerals affect the fertility of the soil to a certain extent, the quality of the soil is due in largest measure to the size of the grains, especially in regard to the relation of the soil to moisture. We speak of a clay soil, or of a sandy soil, and more rarely of a silty soil. The clayiness or sandiness of a soil depends upon the size of the grains; e. g. if the grains are so large that 25 to 100 of them lying side by side will measure an inch then the soil is known as coarse sand. The diameter of very fine sand soil grains is not far from 1-350 of an inch.

A silt soil is still finer, so fine that it may take 2,000 to 5,000 of the soil particles laid side by side to cover an inch space. These would be much too small to be seen with the naked eye. The grains of a pure clay soil are even finer, all of them being less than .005 of an inch in diameter. From this we see that sandy, silty and clay soils are marked

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*The "dry farming" region of North Dakota is more or less indefinite in extent but most of the statements as given apply quite generally, except for the Red River Valley.

off from each other by differences of degree and not of kind. A soil is a sand soil because the soil particles are comparatively large, and a soil is a clay soil because its particles are extremely minute. One never finds an agricultural soil composed of grains belonging entirely to one class. A sandy soil contains grains of silt and clay and a clay soil contains grains of sand.

The presence of clay soil grains has a pronounced influence upon the character of the soil. A soil, for instance, may be known as a clay soil when only a third of its weight is composed of clay grains. If the soil is very rich in clay it becomes very intractable and hard to work. A gumbo soil may contain only 40 or 45 per cent of clay, but naturally a considerable remainder of the soil would be composed of silt grains, which stand next in clay to fineness. It would be quite impossible to farm any land composed entirely of clay. That different soils behave differently towards moisture is well known.

If a soil contains proper amounts of sand, clay and silt such a soil acts most favorably towards moisture, towards tillage and towards the crop. Such a soil is said to be a loam soil.

LOAM SOIL.

A loam soil keeps in good tilth, works with comparative ease, does not dry out rapidly, does not crack open on drying, holds a good supply of moisture, allows moisture to pass thru with comparative ease, contains grit enough to scour and affords a good rooting place for plants and for the accumulation of organic matter decaying to form humus. A soil is known as a sandy loam or a clay loam, depending upon the comparative abundance of the sand grains or of the clay grains.

In an ordinary soil we do not find all of the soil grains separate from each other. This applies particularly to the finer grained soils. The individual soil grains are combined into larger or smaller crumbs or kernels. Perhaps most of the soil crumbs are visible to the naked eye and they may reach half an inch or more across. These soil crumbs are made up of individual grains cemented together.

It is the presence of these crumbs of soil, the particles of which are cemented together by lime or by clay, that gives the heavier soils their good tilth. As is well known, the good tilth of the wet heavy soils is easily destroyed, the soil becomes "puddled." The same thing happens when wet clay is kneaded with the hands. A practical application of this fact upon the farm is the forming of water holes by driving stock around in a low spot previous to the drying. The soil crumbs act in the soil very much as individual soil grains, so far as plowing and cultivation are concerned.

MECHANICAL COMPOSITION OF THE SOIL

It will be well to consider for a moment the mechanical makeup of the soil. In the following table, in part modified from Hall, is given an analysis of some soils, one of them being from Dickinson. The gravel is omitted as it does not form a large percentage of the material. The four classes of sand are so united that only two are given.

TABLE SHOWING MECHANICAL COMPOSITION OF VARIOUS SOILS.

	KIND OF SOIL GRAINS			
KIND OF SOIL	Coarse Sand	Fine Sand	Silt	Clay
Fine sandy loam	15.9	51.8	20.3	10.2
Loam	18.3	36.1	28.5	15.2
Heavy clay loam	15.2	33.6	26.2	20.
Heavy clay	1.	7.9	39.8	52.
Loam from Dickinson	2.2	45.8	34.7	16.

Even the heavy clay soil, so heavy that it was kept only in pasture and not cultivated, contained only a little over 50 per cent of clay. The Dickinson soil is a nice working soil, tho perhaps somewhat lighter than would be desired by many farmers. The character of the soil is affected very much by the relative percentages of different parts. The parts of the soil, such as sand or clay, may differ in quality, this affecting the character of the soil.

WEIGHT OF SOIL

As one may readily imagine, considerable variation in weight exists between different kinds of soil. The following table from King gives the weights per cubic feet of different kinds of dry soil.

Sand	110 lbs.
Half sand and half clay	96 lbs.
Common loam	80-90 lbs.
Heavy clay	75 lbs.
Rich garden soil	70 lbs.

From this we see that the "heavy" clay soils are really lighter than the sandy soils. The terms "heavy" and "light" when applied to soils, refer to the ease in working and not to the actual weight in pounds. An acre of soil 1 foot deep containing no water would weigh from 3 to 4 million pounds, upon the average.

TEXTURE OF THE SOIL

The texture of the soil is affected by the size of the soil particles. As pointed out, soil is made up of particles or grains. Picking up a handful of soil we are generally unable to see in it any holes or pores. This is due to the fact that the soil grains and soil crumbs are so fine. As a matter of fact, soil contains a relative abundance of holes or pores. The space in the soil not occupied by the soil grains is known as the pore space. See Fig. 1.

The ordinary minerals that compose a clay or a sandy soil, or in short the soil particles themselves, are from 2½ to 3 times heavier than water. Upon this basis a cubic foot of soil, if it contained no air spaces, would weigh in the neighborhood of 165 pounds. Therefore the heavy clay soil. for instance, weighing 75 pounds would have a pore space of 54.5 per cent. In other words a cubic foot of dry clay soil, not puddled, would be more than half pores. A sandy soil weighing 110 pounds would have about one-third of its space given up to pores.

The soil particles are of all shapes, and of all sizes up to their limit, thus giving an infinite variation to the shape of spaces between the soil particles. If the soil grains were all spherical it would be an easy matter to illustrate how soil would look when magnified. If we assume that soil particles are spherical they could be arranged so that nearly half of any soil would be pore space, if the soil particles are all of the same size. If they are arranged as closely together as possible, like piled cannon balls or like dried peas in a dish, well shaken down, the pore space would equal about 25 per cent. With spherical soil grains of different sizes an arrangement could be brought about so that the pore space would be considerably less than 25 per cent. It should be understood that in soils found in the fields there are a number of factors affecting the pore space. Illustrations given are only ideal.

SURFACE OF SOIL GRAINS

It is of importance to appreciate the surface area of the soil grains in any quantity of soil. This, together with the pore space, has an important bearing upon the amount of water that a soil may contain. The measurements indicate plainly enough that the surface areas vary with the size of soil particles. This may be illustrated by fencing. A section of land, divided into small fields and each fenced separately requires more fencing than if a fence is run around the entire section. While it is impossible to determine exactly the surface area of any number of soil grains, the results are accurate enough for practical purposes, and withal rather surprising. The following table gives the per cent of pore space and the surface of soil grains in one cubic foot of certain soils.

TABLE SHOWING PER CENT PORE SPACE AND SURFACE AREA OF SOILS

Kind of soil	Per cent pore space	Surface area of soil grains in 1 cubic foot of soil Sq. Ft.
Finest clay soil	53	173,700
Clay loam	47	53,490
Loam	35	45,760
Sandy soil	33	11,030

It is seen that the surface area of the soil grains is relatively enormous. In a loam soil, for instance, with 35 per cent of pore space, the surface area of the soil grains in one cubic foot of soil amounts to more than one acre.

SOIL WATER

Soil water is of three kinds; gravitational water, capillary water and hygroscopic water. The excess water draining off after a heavy rain, under the influence of gravity, is the gravitational water. Gravitational water from rains always moves downward.

If we should examine the soil grains after the gravitational water has drained away, and before the soil has become air dry, we would find that each individual soil grain is covered with a thin layer or film of water, except where adjacent soil grains are in actual contact. The water that is capable of moving from one soil grain to another independent of the force of gravity is known as capillary water.

After the soil has been dried sufficiently so that there is no movement of the liquid, we still find water present. This is known as hygroscopic moisture. The hygroscopic moisture within the soil is probably of no particular value to the plant. There are no sharp dividing lines between these three types of moisture.

Upon referring to the surface area of soil grains in a cubic foot of soil, it is seen that the thickness of the film of capillary water must be very thin indeed, even when the soil contains a relative abundance of water. When the film of water is but .0000275 of an inch thick, a loam soil would contain about 7 per cent of water.

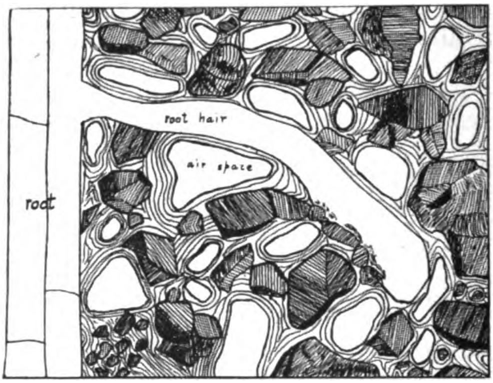


Fig. 1—Shows diagram of root hairs in the soil branching off from a portion of the root. Note the numerous angular soil grains (shaded), surrounded by films of water. The water films are exaggerated. Note the (clear) air spaces. Very greatly magnified. (After Jost.)

AMOUNT OF CAPILLARY WATER

The amount of capillary water that may be carried by different soils varies greatly. The size of the soil grains has an important influence. The larger the soil grains the less will be the surface area of the soil, and as a consequence less capillary water will be found in the coarse grained or sandy soil.

Sandy or loamy soils always contain less water than clay soils, provided equal chances have been given for the soil to obtain water. But a clay soil containing 15 per cent of moisture may be as dry from the standpoint of the plant as a lighter soil that contains 10 per cent of water. The plant will absorb a larger percentage of the water possessed by the lighter soil.

MOVEMENTS OF CAPILLARY WATER

The extent of capillary movement of soil moisture is of great importance, for upon such a movement often depends the success or failure of the crop. We may say at once that very sandy soils allow comparatively limited movement of capillary water. In other words, if the lower end of a column of sand is placed in water the water will rise in the sand only a comparatively short distance. If plants are grown in a sandy soil with permanent water located 8 or 10 feet below the surface, the plants might suffer as much as tho water were 100 feet below the surface. If, however, plants are grown on loamy or silty soil 8 or 10 feet above water, they may be able to withstand extreme drouths.

Loamy and silty soils form the best media for the rise of water by capillary movement. Water does not rise so quickly or so easily by capillary movement thru clay soils; due to the extreme fineness of the clay particles. This explains oftentimes why it is that crops suffer from drouth upon heavy bottom lands at the time that they are thriving upon the higher, lighter soils. In a clay soil, water may not rise rapidly enough from below during a drouth period, to supply the demands of the plant. It is an important fact that water does not rise nearly so high in dry soils as it does in moist soils, nor is the movement so rapid. Likewise the movement of either gravitational or capillary water is much slower downwards in dry soil.

The dryness of the soil contributes to the slow movement of the water thru it in two ways, at least. In the case of the movement of the capillary water, the actual dryness of the soil grains retards the movement of the water. In the movement of the gravitational water, the presence of air in the soil retards movement. When water is poured upon a house plant in a dry soil, one sees air bubbling up thru the water. The down flowing water imprisons a certain portion of the air so that it cannot bubble up thru, or only with difficulty. The presence of air in the dry soil forms a very real barrier against the rapid absorption of moisture. This is one of the reasons that farmers are urged to prevent as far as possible thoro drying out of their soils, for after such thoro drying it takes a comparatively long period of time for them to become wet.

The gravitational water is not used by the plants for the reason that roots do not thrive in water logged soil, or penetrate them to any extent. Except in the Red River Valley, and in certain very restricted areas in the state, free water in the soil does not work to the injury of the crops. It is probable that plants make no appreciable use of the hygroscopic water. It is the capillary water that plants utilize.

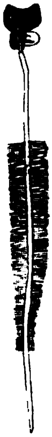


Fig. 2—Mustard seedling, about natural size, showing a multitude of root hairs springing from the young root. These occur near all growing root tips. (After Sachs.)

ABSORPTION OF THE WATER BY THE PLANT ROOT

It is of importance to learn something of the manner in which roots take up water from the soil. As nearly everyone has observed, the roots of any plant divide into smaller roots or send off smaller branches. This division goes on until the rootlets become very small or even minute. Upon a young and growing root, back half an inch or so from the end, may be seen a great number of very small roots or more properly root hairs.

These root hairs are perhaps 1-10 of an inch long and 1-100 of an inch in diameter. They stand thickly upon the root appearing like the nap on velvet. See Fig. 2. Tho small and delicate they have the ability, when growing, to penetrate in among the individual soil grains. See Figs. 1 and 3. It is due almost exclusively to these root hairs that the absorption of soil moisture by the plant takes place. The root hairs live but a short time but as they die new ones are being formed upon the new growth of the advancing root. The root hair, as it forces its way among the soil grains, is enabled to come in very close contact with the soil grains, so close that nothing separates the two except the thin film of capillary water, which has been previously discussed. See Fig. 1.

The root hair is really a plant cell and contains cell sap and living substance. Cell sap in the root hair is generally denser, that is, it contains more dissolved substances, than the capillary water found around the soil grains. As a consequence of this the capillary moisture in the soil enters into a root hair, even against a higher pressure, more rapidly than the water from the root hair enters into the soil. As the root hairs drink up or absorb the moisture from the soil particles immediately surrounding them, then the soil moisture a little ways away from the root hairs moves on to the soil particles adjacent to the root hairs. This movement keeps on towards the root hairs until equilibrium is established—until the pressure or tension of the capillary water at one point is no greater than the pressure or tension of the capillary water at another point.

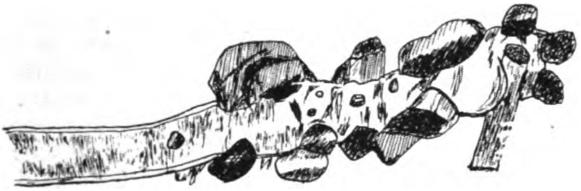


Fig. 3—Shows root hairs adhering very closely to a number of soil grains. The moisture surrounding the soil grains dissolves a portion of the grains. The part in solution may serve as food for the plant. Very greatly magnified. (From Bonn text.)

The work done by each individual root hair is very small, but the almost infinite number of root hairs upon an ordinary plant suffice to absorb or drink up several pounds of water each day.

UPWARD MOVEMENT OF WATER IN THE PLANT

After the soil water gets into the root hairs and into the roots there must be some force to carry it upwards. Let us turn our attention for a moment to the leaves of the plant. Our field-crop plants have green leaves with flat surfaces. If we should examine the under surface of a wheat leaf with a magnifying glass, we would find it pierced with many minute openings. The openings are so small that the prick of the finest needle would seem like a great cave in comparison. Oftentimes 200,000 of them may be found upon a square inch of surface. These openings, known as stomata, are provided with guard cells, which control the size of the opening in the leaf.

Among other things, the stomata allow the moisture from the leaf to pass out into the air. Very early in the day during the growing season, the cells of the leaf are filled to bursting with water or cell sap. This is often indicated by the brittleness of such plants as corn. As the heat and dryness of the day increases, moisture escapes from the leaf thru the stomata. As the cells in the leaf lose some of their moisture they call upon the cells deeper in the leaf for a fresh supply, and as the deeper cells lose moisture they in turn call upon cells or vessels located perhaps in the stem of the plant for still more. Moisture is thus transferred from one portion of the plant to another, much as water is handed on from man to man in the old-fashioned bucket brigade. Eventually the call for moisture extends down to the roots of the plant, even to the root hairs. So it comes about that the root hairs drink up moisture that later is to be given out to the air thru the stomata of the leaves.

The soil water absorbed by the root hairs contains the plant food that is derived from the soil. The plant depends upon the salts dissolved in the soil water for its supply of nitrogen, potash and phosphoric acid. Thus one of the apparent purposes of the movement of a comparatively large amount of water into the roots thru the plant, and out thru the leaves, is to bring to all parts of the plant the soil food which is so important for growth.

HOW WATER IS LOST.

It is evident from what has been said that when plants are growing, water is lost from the soil in two ways. In the first place, water is evaporated directly from the soil.

In the second place, water is lost thru the plant. It is transpired, as just indicated, thru the stomata of the leaves. Water is lost, then, both by evaporation and by transpiration. In growing a crop it is almost impossible to calculate the amount lost in each case, so that both losses are generally figured as one.

It is difficult for man to modify the loss by transpiration. One method of doing this is by growing certain drouth resistant crops or plants, which transpire less water than do crops or plants that are not drought resistant. The plant itself in most cases is able to modify the amount of water transpired, within certain limits. Under certain conditions the stomata close and transpiration nearly stops. Again, the leaves expose less surface at one time than at another. We are all familiar with the fact that during dry August days, the corn leaves roll up each afternoon and unroll during the night. The rolling of the leaf economizes the water of the plant.

In many cases it is comparatively easy to regulate the amount of water evaporated from the soil while the crop is growing. The cultivation of corn, for instance, decreases the amount of evaporation and thus conserves soil moisture.

AMOUNT OF WATER REQUIRED FOR CROPS.

There is great variation regarding the amount of water required for crops. The differences depend upon external conditions such as weather, and upon the variety or kind of crop used. It is claimed, for instance, that more water is required to produce a crop in arid regions than in the humid regions. It is well established, moreover, that it takes less water to produce a crop of corn than it does to produce a crop of oats, the yields being the same. Scientists have made determinations upon the amount of water required for a crop. Probably the best work in this country was done by Professor King of Wisconsin. Professor Widtsoe and Mr. Merrill of Utah, have recently done similar work. The following table shows the results secured by King.

TABLE SHOWING AMOUNTS OF WATER REQUIRED TO PRODUCE DIFFERENT CROPS.

Crop	Tons of water required to produce 1 ton of dry crop.	Acre-inches of water per ton of dry crop.
Barley	464	4.10
Oats	504	4.45
Corn	271	2.39
Clover	577	5.09
Peas	477	4.2
Potatoes	385	3.4

The acre-inches of water perhaps can be better understood by calling them inches of rainfall. It should be stated that these figures indicate not only the water transpired by the plants—the amount of water passing thru the leaves, but also the amount evaporated from the ground.

A study of this table shows at once that the amount required to produce a crop is relatively enormous. The average for the crop is nearly 450 tons of water per acre. A great amount of this water is lost by transpiration thru the plant. Attention is called to the fact that clover heads the list in the amount of water used, while corn uses the smallest amount. Oats stands next to clover. It has been found that wheat uses about the same amount of water as barley.

Professor Widtsoe in his book "Dry Farming" gives the following amounts of water required for the different crops. The amounts as given are for tons of water for each ton of dry matter.

TABLE SHOWING AMOUNTS OF WATER REQUIRED TO PRODUCE DIFFERENT CROPS.

Crop	Tons of water required to produce 1 ton of dry crop.	Acre-inches of water per ton of dry crop.
Wheat	1048	9.22
Corn	589	5.18
Peas	1118	9.85
Sugar Beets	630	5.55

It is seen that the figures given by Widtsoe are much higher, something like 2½ times higher than the figures given by King. Assuming that both results are equally correct, it is apparent that Utah conditions necessitate the use of a larger amount of water than do the Wisconsin conditions. The evaporation conditions are certainly more severe in Utah, and it is claimed by Widtsoe that a greater amount of transpiration takes place under arid and semi-arid conditions to produce an equal amount of dry crop.

King has prepared a table showing the amount of water required to mature different yields of wheat, assuming that the soil was in moist condition at the beginning of the season. The following is a summary of the table:

TABLE OF LEAST AMOUNT OF WATER REQUIRED TO PRODUCE DIFFERENT YIELDS OF WHEAT PER ACRE WHEN THE CROP CONTAINS 40 PER CENT OF GRAIN

Bushels per acre	Total weight of crop, tons	Water used acre—inches
15	1.125	4.5
20	1.5	6.
25	1.875	7.5
30	2.25	9.
35	2.625	10.5
40	3.	12.

From the above table it would appear that when the soil is in good moisture condition at the beginning of the season, and when there is no loss of water by under drainage or surface drainage, 4.5 inches of effective rainfall will produce a yield of 15 bushels per acre, and at the end of the season's growth, the soil will not be so dry as to check vigorous growth. The above table could be applied to North Dakota, but as a general rule at the end of the growing season the soil is generally very dry. If the soil starts in moist, and is dry when the crop is harvested, it is evident that a considerably larger amount of water than 4.5 inches for each 15 bushels of grain would be used.

When wheat or other grain is grown where water has been stored, the plants have a normal root system, extending to a depth of 4 feet or more, and consequently there is much less chance for a comparatively xcessive amount of water to be evaporated. If the water be confined mainly to the top 12 or 18 inches of soil, a larger percentage of the soil water becomes lost, in the same length of time, than if the water were distributed thru a greater depth. Data secured at Dickinson in 1911, indicate that moisture was lost from the top foot of soil alone, at the rate of 10 tons per acre each day for 25 days from June 12 to July 7.

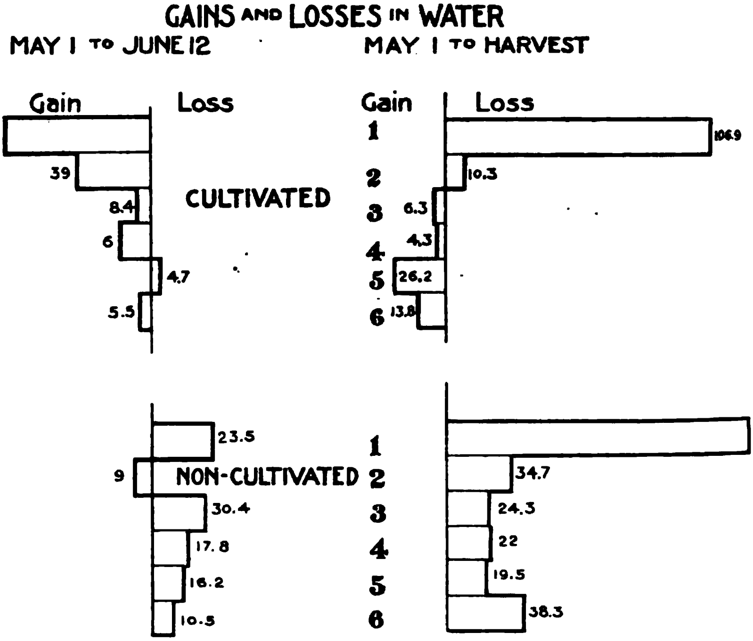


Fig. 4—Shows the gains and losses in tons of water per acre for each foot of soil to a depth of 6 feet, upon cultivated and non-cultivated plats of wheat, from May 1 to June 12, and from May 1 to harvest time, 1911. Note that upon the non-cultivated plats water was lost from every foot of soil during the season, while on the cultivated plats water was gained from the third to the sixth foot. The water conserved amounted to 1.88 inches of rain.

GENERAL RULES.

There are three general rules that should be followed where farming is carried on in regions of limited rainfall. 1. Care should be taken that the maximum amount of rainfall gets into the soil. 2. Great care should be exercised to retain the greatest amount of water after it has once been secured. 3. Such crops and such varieties should be grown that utilize the moisture to the best advantage.

THE THEORY OF THE DIRT MULCH.

If a layer of straw be scattered over ground containing some moisture, but rather dry at the surface, a marked effect will be noticed in a few days. The upper few inches of soil will be seen to have accumulated moisture. The moisture thus accumulated would have been given up to the air and lost to the soil had not the covering of straw been applied.

A layer of dry soil applied to land acts in the same manner as the layer of straw. Because a layer of dry soil may be applied to land from the land itself makes the use of the dirt mulch of almost incalculable value. Without the use of the dirt mulch, "dry farming" would be impossible. The skillful use of the dirt mulch, in such a state as North Dakota, means, in the long run, the success of the farmer. The lack of attention to the soil mulch will inevitably lead to failure.

More specific details regarding the manipulation of the soil mulch will be given later on. Particular attention needs to be given: (1) to the manner of making the mulch, whether by cultivator, disk harrow or what not; (2) to the frequency of the formation of the mulch; (3) to the depth of the mulch and (4) to the character of the mulch, whether the elements be fine or coarse. These factors will depend in varying degree upon the soil, the crop, the weather and upon other conditions.

The following principles, among others, govern the dirt mulch:

1. The effectiveness of the dirt mulch increases with its depth. The practical limit of effectiveness is probably 3 or 4 inches.

2. Increasing the depth of the dirt mulch decreases the amount of available fertile soil.

3. The dirt mulch decreases in efficiency with age.

4. The crumb form of the dirt mulch has a greater resistance to wind action than the dust form.

5. The crumb form of the dirt mulch is more effective than the dust form. (According to King.)

6. Dirt mulches are properly made when the soil is moist.

PLOWING.

The work of plowing is very important for the success of the crop. With poor plowing the yields are generally much lowered and the resulting crop often a failure. King states that the work of the plow is two-fold; to bury the weeds and other trash to where they will be converted into plant food, and secondly, to so alter the texture that a deep and mellow layer of earth is formed from a comparatively hard soil.

The effect of the plow, when the soil is in proper condition, is to shear the soil into thin layers, and this shearing is an efficient form of cultivation. This is illustrated by taking many pages at the corner of an open book and bending them over. It is the tendency of the plow to force the different layers of soil by one another, as the pages of the book are forced. When the soil is too wet, and especially if the soil is inclined to be heavy, the plow instead of forcing the soil into layers, destroys the soil crumbs or granules, thus puddling or compacting the soil. Plows with steep moldboards have the greatest pulverizing action upon the soil. The plow with the less steep moldboards has less tendency to puddle the soil and is of lighter draft.

TIME OF PLOWING.

The plow is perhaps the most efficient tool we have in forming a soil mulch. The loose layer of soil formed by plowing effectually prevents the rise of soil moisture from the deeper layers. The time of plowing then must be of much importance in semi-arid districts. When plowing is to take place between two successive croppings, and there is moisture to conserve, the plowing should be done as soon as possible after the first crop is removed. This rule is an excellent one but it often needs some modification. Plowing should not be done when the soil is dry. The soil at harvest time is generally dry and if the stubble be left uncultivated this dry condition may become even more acute, weeds grow and seed readily in the uncultivated stubble after removal of the crop.

The use of the disc harrow to form a mulch upon the newly made stubble will generally put the soil in good condition for plowing in the course of a few weeks. This will be discussed later. The question of holding the winter's snow is of considerable importance. If the land can be put into favorable condition for fall plowing, it would appear to be a doubtful policy to let the land go, untouched until spring. We need more knowledge on this point than we have at present.

DEPTH OF PLOWING.

There is much dispute regarding the proper depth of plowing, and it is impossible to lay down any hard and fast rule governing it. Much depends upon local conditions of the soil and upon the time of year. Speaking generally heavy soils need deeper plowing than lighter soils. Plowing done in North Dakota, probably not averaging deeper than 4-4½ inches, is certainly not deep enough. There is scarcely a question but what the depth should average 6-8 inches. An advantage in deep plowing is the development of a better reservoir for the reception of moisture. If the land has not been plowed more than 3 or 4 inches deep for a period of years, a hard plow sole may become formed thru which rains penetrate with difficulty. A mellow depth of but 3 or 4 inches allows a comparatively small amount of water to sink in.

If a soil that has been plowed only 4 inches deep becomes dried out during dry weather, then a rain of three-fourths of an inch is sufficient to bring that depth to a point of saturation. A torrential rain will not readily sink into the hard soil which has not been plowed, and as a consequence, a torrential shower of one inch, which seems to occur on the average about once a season, would run off in part. If the plowing had been done to a depth of 8 inches, twice as much rain could be taken into the soil before danger of run off. Furthermore, deep plowing has a tendency to increase the depth of bacterial action, thus rendering the soil more fertile.

DISC PLOWING.

Because a disc plow can be made to work upon soil that is too dry for the use of the moldboard plow the disc plow is often recommended. It should not be forgotten that plowing or harrowing should be done when the ground is in proper tilth, when it is not too wet nor too dry. Unless a considerable period of rather rainy weather intervenes between dry plowed land and the crop, the crop is apt to suffer severely. If plowing is done upon dry land, the soil is turned over in lumps and is not properly sheared into layers. A lumpy seed bed is formed rather than a mellow one. It takes a relatively enormous amount of work to transform the lumpy seed bed into one of good tilth.

It must be understood that soil should not be plowed when dry, if avoidable. If the land must be plowed when dry, the disc plow may be preferable, provided the work is well done. An important point with the disc plow is the necessity of taking narrow furrows, preferably 8 to 12 inches wide, thus increasing the expense. When the soil is in good condition, it is generally considered that a better job can be done with a stubble plow than with a disc plow. The disc plow has a value in breaking up the plow sole, if one has been formed. It may be that some one of the newer types of disc plows may be more efficient than is commonly supposed.

SUBSOILING.

Subsoiling is the deep stirring or plowing of the soil. Subsoiling may be accomplished by a very narrow form of plow, perhaps only 2 or 3 inches wide at the bottom, working in the botton of the furrow thus following the ordinary plow. The same results are accomplished by the disc plow when the two discs are arranged tandem, the hinder one going the deeper.

Aside from the large expense, one drawback of subsoiling in humid climates is the danger of puddling the soil. In semi-arid regions the danger is that the soil is left too open. This would result unfavorably in two ways; capillary action would be broken so that moisture would be cut off from below, and the plant roots might find it impossible to penetrate the more or less open layers left by the subsoiler, with a consequent stunting of crop. The main result of subsoiling in semi-arid regions would be the moisture effect.

It is claimed by the makers of certain modern disc implements that the cost of the work is now reduced to within reasonable limits. If this be true, it may be that the practice will find much wider use than has been accorded. With our present knowledge, it is unsafe to generalize as to the fitness or unfitness of subsoiling.

Subsoiling experiments carried out in southwestern Minnesota at the Coteau farm upon loam soil, decreased the yields in practically all cases. Subsoiling the clay soil of the

Red River Valley at the experiment station, to a depth of 8 inches below a 6-inch furrow increased the yields when done in the fall for the next season's crop, but decreased them when done in the spring for the same season's crop. In no case were the yields increased enough to pay for the extra cost of subsoiling.

TILLAGE BEFORE AND AFTER PLOWING.

Secondary only to plowing is the tillage before and after plowing. It has been customary in plowing to take the field as left by the crop. This applies more particularly to grain fields, as when corn or potatoes are in crop the land is generally not plowed. Under dry farming methods it is commonly conceded quite important to cultivate stubble land, including corn stubble, at the time the crop is taken off. This practice is not much used in North Dakota, but it might be well worth while to disc the stubble at the time of harvesting the crop, in the drier portions of the state.

The ripe grain does not remove much moisture by transpiration and further protects the ground from winds and sunshine. When the grain is cut this protecting covering is removed and consequently the moisture in the ground escapes much more rapidly than it would if a surface mulch were upon the soil. Discing the stubble has generally proven a valuable practice. The good effect is noted not only upon the succeeding crop, but the top soil is put in much better plowing condition by increasing the moisture, thus in part overcoming one of the bad accompaniments of fall plowing in semi-arid regions. The plowing also is made easier. The mulch formed by the disc would doubtless allow a better connection to be made with the underlying subsoil.

EFFECT OF DISCING STUBBLE.

Duplicate plats were disced at Dickinson in 1911 in comparison with plats left undisced at the time of harvesting the crop. About a month later the moisture was determined and the following gains and losses were obtained for each foot of soil.

TABLE SHOWING GAINS AND LOSSES OF SOIL MOISTURE DUE TO DISCING

Depth of Soil	INCHES OF RAINFALL	
Feet	Gain	Loss
1	1.31	
2		.29
3	.07	
4	.13	
5	.40	
6	.95	
Total	1.86	.29

The net gain for 6 feet of soil ....1.57 inches

It is seen from the table that the gain here, as an average of the 2 plats, amounted to 1.57 inches of rain. If the gain had been but half an inch of water the work done would have been amply repaid. In this instance there was also a very noticeable effect upon the ease of plowing. The land that had been disced, plowed much easier and after plowing the disced plats were darker colored, due to the extra moisture in the soil. Not only was the plowing done more easily, but what perhaps is of more importance, the plowing was done more efficiently.

Plowing the stubble not only furnishes a mulch to conserve the moisture, but loosening the soil allows the rains to penetrate more easily. The working of the stubble in with soil is doubtless of some advantage.

CULTIVATION AFTER PLOWING

After plowing, the land should be worked as soon as possible. It is a common practice to have a cultivator attachment upon the plow so that a soil mulch is formed at the time of plowing. It is very common for the moldboard of a plow to leave a smooth and more or less glazed surface, which gives an almost ideal condition for the rapid drying out of the soil. Some farmers attach a section of a harrow behind the plow in such a way that when the plowing is finished the ground has been covered by the harrow two or three times.

If there is no cultivator attachment on the plow it is very important that the plowed land be harrowed twice a day as it is plowed. The escape of moisture from newly plowed land is extremely rapid, depending, of course, upon the moisture of the soil and the atmospheric conditions. After the preliminary harrowing after the plow, the land may be fitted with a disc harrow. If the ground is quite moist at the time of plowing the teeth of the disc may be set straighter than if the ground is dry. Double discing, that is, lapping half, is generally to be preferred as then the ground is left more level. With the discs set more or less straight, the weighted disc harrow does quite efficient packing and this is of value particularly on spring plowing. If the land is sufficiently fitted with the disc, it should then be covered with a peg tooth harrow, to level the ground and to finish getting the seed bed into good condition.

SEED BED

The kind of seed bed desired depends upon the kind of crop to be grown. The seed bed for smaller seeds needs to be finer, mellower and more firm than the seed bed for the larger seeds. In preparing ground for alfalfa, for instance, it is necessary to put much more work upon the land than if the ground is being prepared for larger seeds.

There are considerable advantages in securing a firm seed bed in semi-arid regions. If the upper 6 or 8 inches of soil is very moist and open the ground will dry out more readily than if the soil is compact. The air, as it is forced in and out of the moist soil by wind currents or by other means becomes a soil drying agency. For each entrance and exit of the dry air, the soil loses moisture. Therefore a compact seed bed is one safeguard against loss of moisture. It should not be forgotten, however, that the surface should be kept in a mulchy condition to prevent the loss of moisture.

CULTIVATING THE GROWING CROP

Under semi-arid conditions, cultivation is of prime importance in preventing the loss of moisture, as has already been explained. In addition, cultivation is of great value in killing weeds, and in getting air into the soil. The oxygen of the air is necessary for the proper growth of the roots, and for the support of certain bacteria which work upon nitrogen for the use of the plant. It used to be a saying that "cultivation is manure." This statement today will hardly pass muster, but by conserving soil moisture and by liberating plant food, the cultivation of the crop accounts for a wonderful increase in plant growth.

CROPS FAVORABLE TO INTERTILLAGE.

There are certain crops that lend themselves to cultivation in semi-arid regions because of the fact that they are naturally grown under intertillage conditions. Such crops, for instance, are corn, potatoes and root crops. Practically nothing has been done in the way of growing hay crops as cultivated crops. This is due mainly to the fact that grasses and clover are not adapted to this kind of culture. This restriction perhaps does not apply to the alfalfa crop, for it is likely that it will pay to grow alfalfa in cultivated rows for hay production, if the rainfall or if the soil is too light to allow the crop to be grown by ordinary methods.

CULTIVATION OF CLOSE-PLANTED CROPS

While the close-planted crops are not commonly thought of as tillage crops, it has been found that under certain conditions and with the exercise of proper judgment, they may be profitably cultivated. This statement applies to the small grains, to alfalfa and even to grases and clover. Regarding the cultivation of thickly spaced crops there are many practical difficulties to surmount. One of the most important of these is the securing of machinery best adapted to the work. Regarding this, three main points are to be considered: (1) ease of draft and amount of ground to be covered; (2) efficiency of the dirt mulch, and (3) the least possible resulting injury to the crop. Another point that must receive careful study is the determination of the kinds of soil that are most benefitted by cultivation.

GENERAL PRINCIPLES OF CULTIVATION

As one purpose of cultivation is to destroy the weeds, the cultivating should be undertaken when the weeds are small, before they have thrown out more than two or three leaves. Another value to be gained by cultivation is the increase of fertility in the soil. This increase in fertility is brought about largely by the formation of nitrates by bacteria. Cultivation for this purpose should be undertaken during the early period of the plant's growth, and such cultivation should be relatively deep, say 2½ to 4 inches.

The third and main necessity for the cultivation of crops, is the conservation of soil moisture. Soil moisture should be conserved as soon as possible after heavy rains. The main cultivation of the crop should be in June during the early growing portion of the season, at the time of the heaviest rains.

We will suppose that from the rains of May a quantity of water has been stored in the soil. This water will approach near the surface of the ground, but it will be held in the soil provided a soil mulch is formed. It now requires but a slight rain to form capillary water between the stored water and the surface of the ground. After the ground is wetted, from the surface to where the water is stored, it takes but a very few drying days for a comparatively large quantity of water to escape so that the soil may be drier within say 36 hours after a light rain than it was previous to the rain, or than it would have been had no rain occurred.

Later in the season, when the period between rains is longer, a deeper layer of dry soil is naturally formed near the surface of the ground, with a consequent more efficient mulch. In such cases light showers may not act injuriously in abstracting the stored water of the deeper layers. It is well known in the semi-arid regions that if the crop has a relative abundance of stored moisture upon which to draw, it can pass thru comparatively long periods of drouth without much injury. It should not be forgotten that the cultivation of the crop in June provides for the storing of moisture which will carry it over the drouthy periods of the growing season.

All cultivation for the purpose of storing moisture and increasing fertility should be as level as other conditions permit. Soil which is left rough dries out more rapidly. It should not be forgotten, also, that where the soil is left rough the fertility of the increased amount of the dry soil is lost to the plant, for when the soil is dry fertility is not available.

PACKING THE SOIL

Packing or solidifying the soil has a very appreciable effect upon the movement of the soil moisture. In the movement of capillary water it is absolutely necessary that the soil particles be very close together. The flow of capillary water is increased by reducing the spaces between the soil grains, or by packing the soil.

King has shown that with the use of an ordinary flat roller, the moisture of the soil may be affected to the depth of 54 inches. The first effect of rolling, by increasing the capillary movement of water, is to cause the upper layer of soil to become wetter and the lower layers to become drier. If, after rolling, the surface of the ground is allowed to remain firm, the movement of the water continues until the whole soil column becomes drier than it was before rolling. Rolling the soil then, increases the surface moisture at the expense of the moisture in the deeper layers, and finally decreases the moisture in the entire column.

The practice is only allowable in semi-arid regions when moisture from the subsurface can be spared for the use of the top surface or when a capillary connection with the unplowed soil is to be made. If the subsoil is comparatively dry, it may be a very bad practice to reduce its water supply. It should not be forgotten that the deeper stored water is

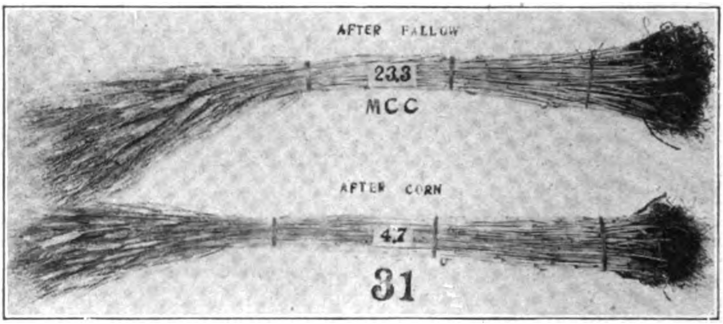


Photo by Thysell

Fig. 5—Two samples of Kubanka wheat from sq. yd. areas grown on Dickinson station co-operative plats in 1911. The yields are on the bundles. Note the similarity of straw but the great divergence of yields. Note the heavy heads of upper bundle. With a little more water at the critical time, the lower sample would have given a good yield. A comparison of this figure with Fig. 6, with certain facts leads one to believe that if the variety of wheat had been a fife or blue stem, the yield on the corn land would have been considerably greater.

much less liable to evaporation than the water next to the surface, and it should also be kept in mind that roots of field-crop plants go deep in semi-arid regions, so that the deeply stored water may be as efficient as the water near the surface. It is found in semi-arid regions that there is a tendency, particularly for the third foot, to become very dry at the time of crop maturity. It might be well not to induce the upward movement of stored water at or immediately before the sowing of the crop.

When the soil is to be firmed, it is better to use a tool that leaves the surface rough or that does not interfere with the soil mulch already formed. There are various kinds of corrugated rollers, combination rollers and packers, and subsurface packers. The weighted disc harrow with straight discs, serves as a subsurface packer. The soil should be firmed enough to establish a good seed bed and to establish capillary connection between the newly plowed and the unplowed soil. This is especially true when manure, trash or heavy stubble has been plowed under. The subsurface packer, or any tool that firms the soil probably does good work in reducing the air spaces of the soil, thus hindering its drying out, provided always that a dirt mulch be left upon the surface.

The press drill is a tool which practically adds the value of the roller to the drill. The soil is pressed only where the seeds are buried thus leaving a mulch between the rows of grain. The pressing of the soil around the seeds tends to bring moisture to them and so hastens germination.

DRY FARMING MACHINERY

Considerable has been said in different places regarding machinery best adapted in the conservation of moisture. It should not be forgotten that where special attention must be given to the conservation of moisture that extra crop cost is entailed. Machinery therefore should be purchased and used on the basis of its making a profit for the money expended. It may be said at once that the plow, the disc harrow, the peg tooth harrow and the corn cultivator are the really essential tools needed to conserve moisture and to produce a good seed bed.

One should study the matter carefully in buying additional tools, and especially is this true where the outlay can be illy afforded. It is very important that the tools that are owned be kept in good conditon. It is a very common thing to see the teeth of the peg tooth harrow, for instance, worn quite flat on that part working against the soil. This is the cutting edge and should be kept sharp. A few rather general-purpose tools kept in good condition, combined with the proper knowledge of their use, will do vastly more efficient work than double that number of specialized tools used without expert knowledge.

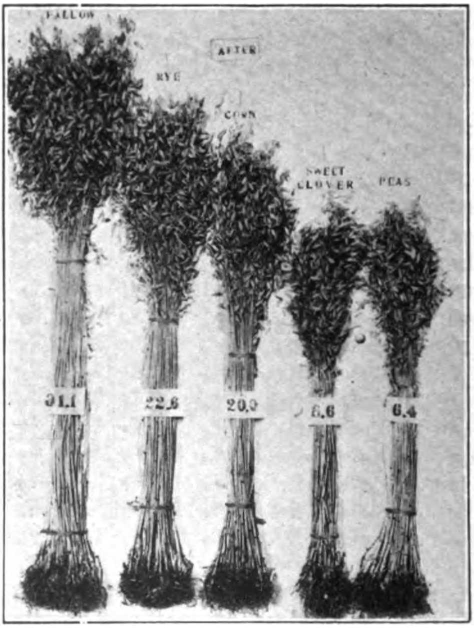


Photo by Thysell

Fig. 6—Samples of Swedish Select oats in 4-year rotations from sq. yd. areas grown on Dickinson station co-operative plats in 1911. Rye as green manure has given better yields than the legumes as green manure. The reason for this is not clear but perhaps may be associated with substances derived from the decaying legumes more or less toxic in character, for a short time after the green manure has been turned under.

DRY LAND CROPS

WHEAT

In strictly semi-arid regions wheat is the main dependable crop. Wheat has been the main crop in North Dakota up to the present time, and while it will continue to be an important crop for many years, the outlook for its continuous successful culture without rotation, in the future is not good. In the drier portions of the state it is evident that there is not sufficient moisture to enable wheat to follow wheat at a profit. In the more humid portions of the state, plant diseases are so abundant that continued wheat growing upon one piece of soil cannot be carried on with success. It may be possible to get two crops of wheat in succession at a profit but generally this is apt to be the limit.

The small grains have a very drying effect upon the soil, it is evident that wheat will be no more successful after other small grains than wheat, where water is the main limiting factor. There seem to be two alternatives. Wheat may be grown after a cleanly cultivated crop of corn, or after a clean summer fallow. While a good crop of wheat may be harvested when grown after corn in certain portions of the state, the possibility of doing this where the annual rainfall is 17 inches or less, is still a matter of doubt. The rainfall at Dickinson for 1910 was about 91 per cent of the normal. During the growing period of 1911, up to the 29th of July, the rainfall averaged 67 per cent of the normal. Wheat of 1911 grown after a well cultivated corn crop of 1910 made yields on the average of less than 5 bushels per acre. Wheat grown under the same conditions but on land that was summer fallowed in 1910 yielded over 22 bushels per acre. Wheat at the Dickinson station has always given good results upon corn ground, except in 1911, but the rainfall has been above normal, either the year the wheat or the corn was grown. Whether spring wheat can be grown profitably upon summer fallowed land in those regions having a summer rainfall, is not yet decided.

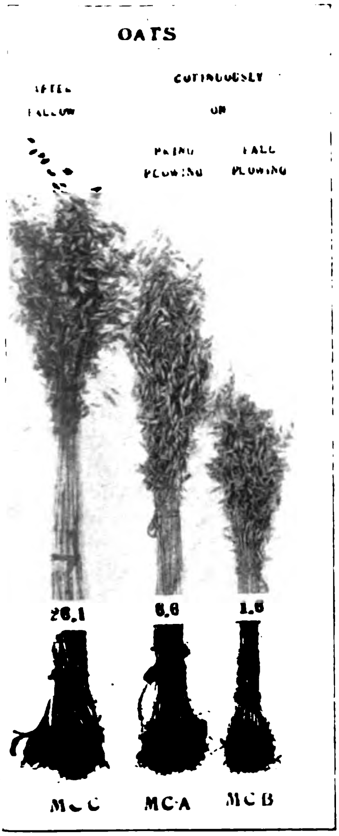
The varieties of wheat mostly grown at the present time are various types of the fife and blue stem, both beardless. Durum wheat is grown considerably in different portions of the state, as is also velvet chaff. Both of these sorts contain well marked varietal differences. The physiological relationship of the durum wheat to the soil and climate, moisture included, has not been worked out with much care. It is likely that the durum wheat is not as thoroly drouth resistant as was once supposed.

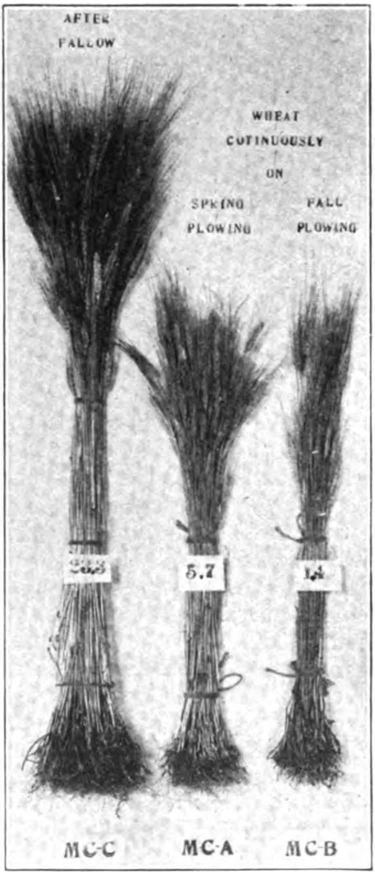
FLAX

This crop is grown to a good advantage upon virgin soil. This is especially true if the land has been broken the year previous, thus allowing the rotting of the sod and the accumulation of moisture. Whether flax is to be a successful crop upon the older soils of the state will doubtless depend largely upon sane and conservative methods of crop rotation and upon proper seed treatment and selection. The fact is patent that flax has been generally abandoned as the lands have become older, tho there has been some strikingly successful flax fields upon some of the older lands.

OATS

As has been indicated it requires more water to mature a crop of oats, pound for pound, than it does a crop of wheat or barley. Oats then is a somewhat expensive crop to raise





Photos by Thysell

Fig. 7 **Fig. 8**

Samples of Kubanka wheat and Swedish Select oats from sq. yd. areas grown on Dickinson station co-operative plats in 1911. The yields are on the bundles. The fall plowing was done in dry soil. Note the heavy yield upon the fallowed plats.

under semi-arid conditions. It is very likely that much of the energy expended on the oat crop in North Dakota could better be utilized in the growing of other crops which do not require so much moisture. While oats and timothy hay are the standard feeds for livery horses, farmers will find that they will get very good results by feeding grains other than oats in connection with the coarse feeds. A mixture of speltz and corn, for instance, will be satisfactory during most of the year.

Considerable increase could be secured in the oat crop in North Dakota if attention were paid to the varieties grown. While it is not possible to name the varieties that are absolutely the best, the annual value of the oat crop would be increased in North Dakota several hundreds of thousands of dollars if no other varieties were grown than the Kherson, Sixty Day, and Swedish Select. This statement does not apply to the Red River Valley.

BARLEY

The barley crop in North Dakota seems to be rather more successful than the oat crop, especially when some care is taken in the preparation of the land. Barley demands less water than oats, so when the barley crop receives favorable field conditions better comparative results will generally be secured when the moisture is deficient.

In the more humid regions of the state the 6-rowed varieties are best adapted, but where the moisture is more deficient certain 2-rowed varieties seem to yield better. Results from Montana and South Dakota seem to confirm this statement. This applies to certain Swedish barleys, such as the Hannchen and Swan Neck. It has not been found that any of the hulless barleys yield as well as either the 6-rowed or 2-rowed varieties of hulled barley. It would be more profitable for the state as a whole no doubt to devote more attention to barley than to oats, than is done at the present time. The hulless beardless barleys seem to be well adapted for hay production.

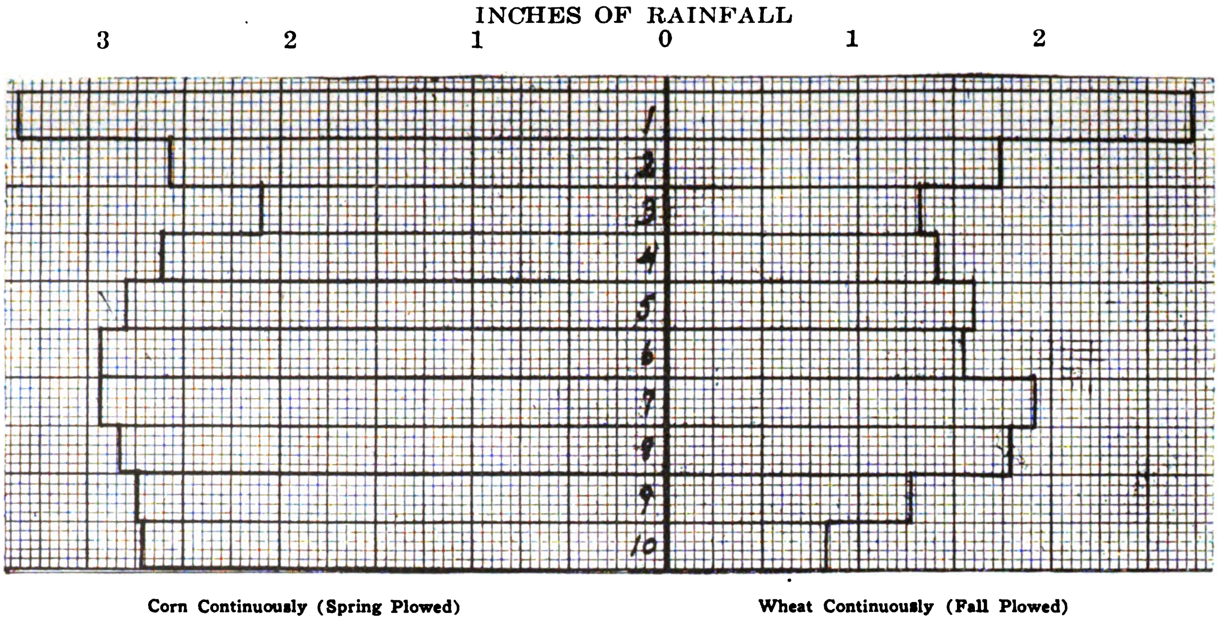


Fig. 9—Shows inches of water for each foot of soil to a depth of 10 feet as determined in the fall of 1911 upon plats "A," co-operative plats. The crops and treatment are indicated. The depth of water for each foot is drawn to actual scale. There were 27.60 and 16.16 inches of water for the corn and wheat plats, respectively, at time of sampling, but a portion of this water was unavailable, of course. Five crops have been removed from each plat.

WINTER GRAINS

The successful culture of winter grains in North Dakota would mean much to the wealth of the state, for winter grains yield higher than corresponding spring grains. This increased yield is due to a variety of conditions. In one word, winter grains are better able to utilize the moisture.

Winter rye is generally successful in the state as regards hardiness, and where it is hardy the crop is very satisfactory. Its culture is increasing quite rapidly. The culture of winter wheat in the state is uncertain. It evidently cannot be grown on summer fallow, as it is too liable to kill out. It is fairly successful when sown in small grain stubble, if sufficient moisture is present to germinate the seed and to give it a good start. If sown in standing corn it may be grown with reasonable success, if the stalks are left standing.

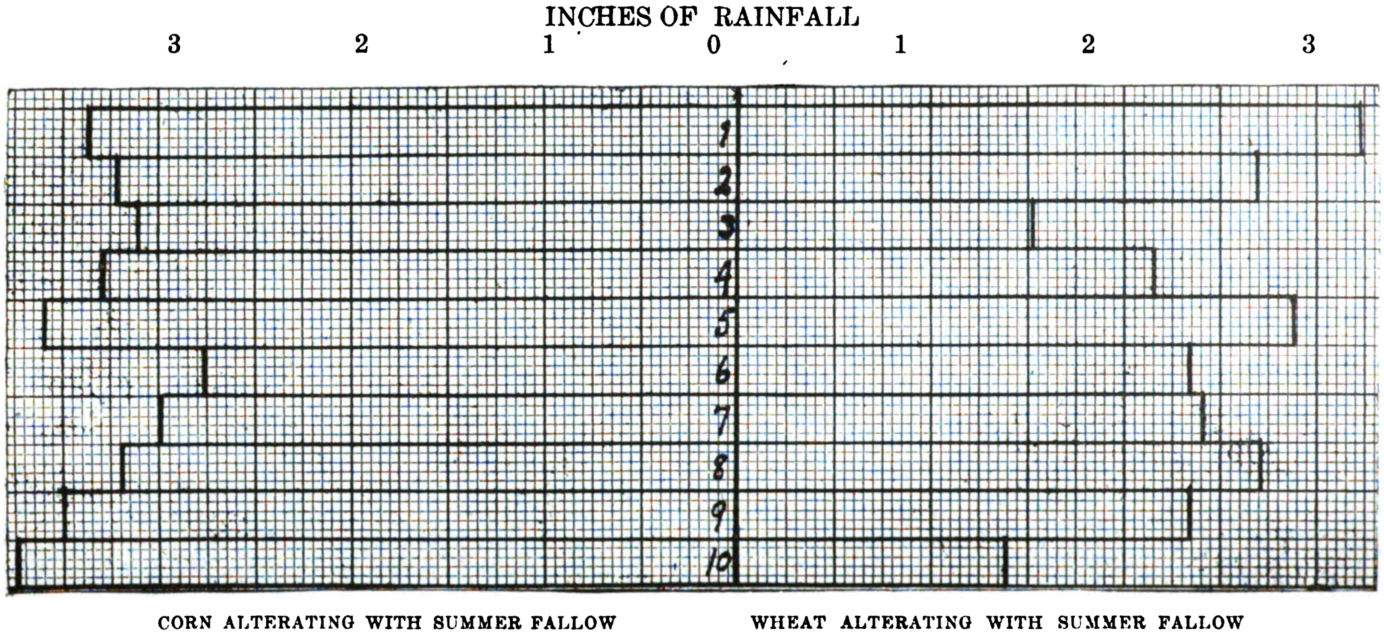


Fig. 1)—Shows inches of water for each foot of soil to a depth of 10 feet as determined in the fall of 1911 upon plats "C," co-operative plats. These plats were cropped in 1911, making the third alternate crop. Depth of water drawn to actual scale. There were 32.72 and 28.64 inches of water for the corn and wheat plats, respectively. Note that the continuous corn plat of Fig. 9 contains 4 inches more of water than the plat that has grown wheat every other year. Note the very wet condition of the tenth foot corn compared with the tenth foot wheat.

CORN

The corn crop in North Dakota is rapidly assuming considerable proportions as indicated by the following table of acreages. Wheat is also given as a comparison.

TABLE GIVING ACREAGE OF WHEAT AND CORN IN NORTH DAKOTA.

	ACREAGE	
Year	Wheat	Corn
1904	4,560,000	90,000
1909	6,625,000	195,000
1910	7,221,000	214,000
1911	7,590,000	289,000

We see from this a healthy increase in the corn acreage and there is no doubt but that this will continue until the acreage is sufficient to meet the demands of a properly balanced system of farming.

As has been pointed out, the lack of moisture over a considerable portion of the state, and the presence of plant diseases, prevents the continual growing of small grains. It has been estimated that where the annual precipitation amounts at least to 17 inches, a profitable crop of small grain may be raised after a cleanly cultivated crop of corn. Perhaps this may be done where the rainfall is less than 17 inches, but of this we are not certain at the present time. With a rainfall of 17 inches, apparently enough moisture can be conserved to insure a succeeding grain crop. The extra moisture conserved during the time of the growing of the corn probably acts beneficially in the formation of nitrates. It is likely that many of the plant diseases, affecting the small grains, receive a temporary setback during the time of the year that the corn is being grown.

While the value of the corn crop is very great as regards its effect upon the succeeding grain crop, this is perhaps secondary to the favorable effect upon the live stock industry, and consequently upon a reliable income. It has often been supposed that one of the main drawbacks of corn growing in North Dakota would be the great difficulty of securing adapted seed. It has been found that the trouble lies almost entirely with the corn growers, for sufficient care is not taken with the seed in the fall. It is allowed to freeze while moist and is thus killed. Even greater care should be taken in securing seed corn than in securing seed potatoes. The seed corn should be harvested and put to dry, away from frosts, as early as the 1st of October. If this be done one may be certain of the viability of the next year's seed.

ALFALFA

Alfalfa is a new crop for North Dakota and it is doubtful if at the present time there is as much as a section of land devoted to alfalfa in any one county. While alfalfa has formerly been associated in large part with irrigation, it is becoming evident that the crop may be made particularly adapted to dry farming conditions. The root system of the alfalfa plant plainly indicates its adaptation to dry regions. It is adaptable to great extremes of moisture supply if the soil be given good drainage. While producing wonderful yields with an abundance of water, it will make a good showing under a rainfall of 15 inches, provided that it be given proper culture.

Its water requirement is probably about the same as that of clover thus being higher than the water requirement of wheat. Its extensive root system, when given proper opportunity for development, together with its long seasonal growth, due to its perennial habit, offsets in considerable measure, its comparatively high water requirements.

Alfalfa is commonly given a thick seeding. The method is allowable if the roots go down to permanently moist soil. If the alfalfa depends upon the rains for its moisture supply, and it must under dry farming conditions, thick seeding will not produce good results. Where moisture is deficient, the alfalfa plant must be allowed to develop an extensive root system and this is possible only where thin seeding is practiced.

For the best results in the drier areas it may be advisable to plant the alfalfa in rows so that it can be cultivated. This statement certainly applies where the seed crop is to be made prominent. If the alfalfa seeding is thin enough so that each plant may develop a good root system and so develop more or less of an individuality, and further, if the alfalfa stand be thin and be given a reasonable amount of cultivation to prevent excessive evaporation, there is no question but what the alfalfa will make the best possible use of the water that falls. If alfalfa be given favorable conditions it ought to yield in North Dakota an average of 2 tons per acre annually. Care should be taken that hardy seed be sown.

SUMMER FALLOW

Mention has been made of the growth of grains upon summer fallow. Land to be summer fallowed should be disced at the time of harvest. The land may be fall plowed or if preferred it may be plowed the following June, during the first half of the month. If plowing is deferred until June the stubble should be disced again early in the spring, preceding the plowing. After plowing, the land should be worked to conserve the moisture. A soil mulch should be maintained to prevent evaporation. The following spring grain is to be sown upon the summer fallow. Thus the crop will have the benefit of the moisture that has been saved the previous season. Many of those that practice summer fallowing do not seem to have moisture conservation in mind, and consequently its main value for this state is lost.

USE OF MANURE

The barnyard manure obtainable should be well utilized. When barnyard manure is to be plowed under it should precede a cultivated crop, such as corn, roots or alfalfa; or it should precede summer fallow. The manure should be applied as a top dressing if used in connection with small grains. It is utilized more easily in a compost condition, altho manure has lost some of its value when composted. When well composted, it is claimed that the plant diseases present in the straw are killed. It is found that barnyard manure plowed under is an efficient agency in subduing ''gumbo'' soil.

PRINCIPLES OF CROP ROTATION

No effort will be made in our limited space to outline rotations, but it may be well to suggest a few governing principles. The live stock industry should form a very integral portion of dry farming, vastly more than it does at the present time. It must not be forgotten that the whole basis of farming rests upon successful crop production and it is to this element that our attention is first attracted. The basis of successful crop production is the soil, and in most of North Dakota it is the water supply of the soil that is the chief limiting factor. Therefore some part of any successful crop rotation which includes the small grains, must have for one object, the conservation of moisture at some period of the rotation.

Put in other words, this means that a rotation containing small grains must contain an intertilled crop, such as corn, demanding less moisture for its maturing than fell during the growing season, so that at time of harvesting such a crop, there will be a greater quantity of moisture in the soil than there was at time of seeding.* As far as this principle is carried out in North Dakota, the cleanly cultivated corn crop should form one of the basal elements of rotation.

If, however, the moisture is insufficient both for growing a crop and for allowing a portion to be conserved, an amount sufficient to practically insure the succeeding crop, then any such intertilled crop, as the corn crop, must be put in the same class as a grain crop. From the standpoint of the results secured it must be considered a moisture dissipating crop rather than a moisture conserving crop. Where this is the case it will evidently be necessary to utilize the clean summer fallow in place of the intertilled crop.

Where money crops are made a feature of any system of farming, there is a constant tendency for humus and organic matter to be lost from the soil. This loss has an injurious effect upon the physical properties of the soil and often in a marked degree. After having lost humus and organic matter a soil is more apt to "blow." Furthermore such soil is not so easily tilled when wet and is more apt to run together or puddle. The water holding capacity of the soil is decreased by the loss of humus, as humus is a valuable storage agent of water. With these facts in mind it is of the greatest importance that any system of rotation which has for its main feature the production of grain crops should look towards the retention of the humus within the soil. The desired results may be secured (1) by the application of barnyard manure; (2) by the plowing under of green manure crops, such as winter rye or sweet clover; (3) by the inclusion of pasture into rotation,—the rotting of the grass roots or of the legume roots sufficing to render the land more like the virgin prairie.

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*From a certain viewpoint this method would work only in theory as the corn would utilize the available moisture for increased growth, thus leaving no extra moisture at the end of the season. The explanation seems to be that because of the climate, the varieties of corn grown in the state have been bred to dwarfness and so growing dwarf do not produce the dry matter per acre that the available moisture would seem to warrant. The climatic conditions during the season, the winds for instance, may have a dwarfing effect upon the corn plant.

While the growth of legumes may not be necessary to maintain the supply in the soil, of nitrogen in a usable form, it probably will be a matter of economy to include legumes, say alfalfa, in the rotation for this purpose, thereby enriching the soil.

Certain plant diseases, affecting especially the small grains, tend to accumulate in the soil. According to Bolley, the rotation of crops, introducing an intertilled crop, grasses or legumes, holds such diseases in check. Crop rotation, therefore, is of benefit from this standpoint.

LIVE STOCK.

While often it is possible to carry on farming successfully upon new lands independent from the growing of live stock, provided moisture is sufficient, yet it is extremely doubtful if such a method could be continued indefinitely. It might be possible to plan a system that would bring in returns for many years, if it were strictly followed. A study of the conditions of the state shows that there is really no state-wide system of farming. We find rather a lack of system. To confirm this statement it is only necessary to indicate that one or two good years in succession will change very considerably the farming methods of the area involved. The corn acreage decreases, live stock is disposed of and the energy of the farmers is devoted largely to wheat and flax, they endeavoring at the same time to cover large areas with careless tillage. This method is continued until a season of drouth with the consequent total loss of the crop.

The presence of live stock upon the farm introduces a stability to the agriculture which is not secured when the efforts of the farmer are directed along the lines of mere crop production. A man with dairy cows, for instance, has established a system which regulates and governs his income. It may be that for a period of 15 years upon new lands the income of the dairy farmer would be no greater than the income of the man raising money crops, provided the one raising the crops followed sane and conservative methods.

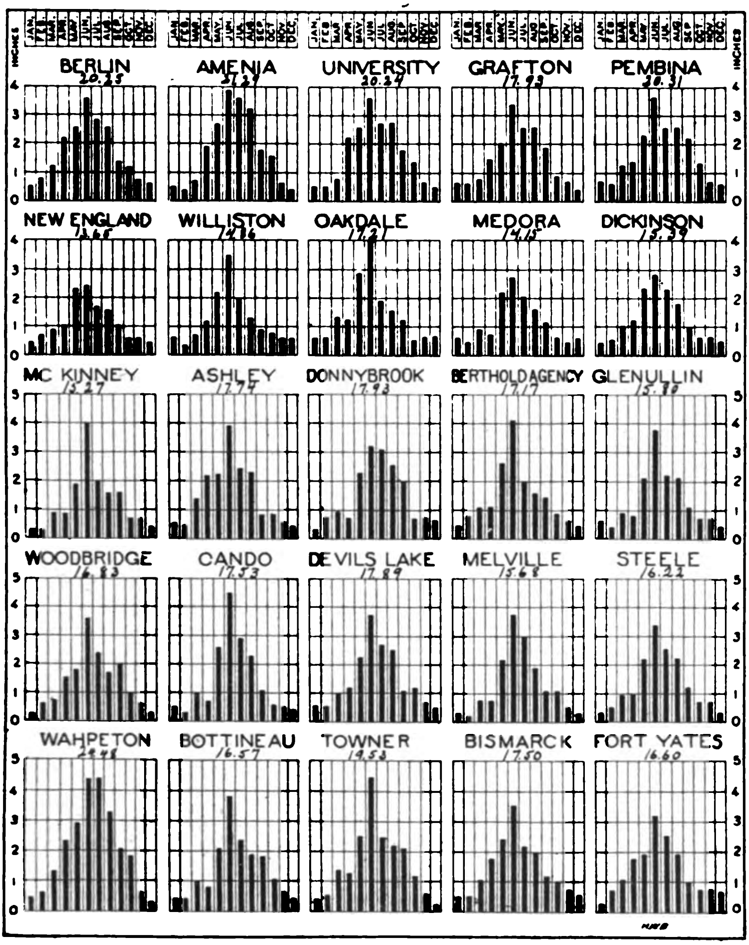

Fig. 11. Shows precipitation both monthly and annual at various selected points in North Dakota. Note the high June rainfall in nearly all cases. (After O. W. Roberts, Weather Bureau.)

Even admitting the truth of this we find that such a result does not work out in practice. After a good season, the farmer is willing to increase his hazards that the season following will be equally as good. The keeping of the dairy cow enforces and makes necessary a safe and more certain method of farming.

In the long run the problem of soil fertility becomes a prominent one. While the quality and fertility of the soil may be retained by growing legumes and the application of mineral manures yet it is doubtful if such a method is economical. The fodder necessarily produced upon the farm in the rotations can be disposed of economically only thru live stock, as a general rule.

GENERAL CONDITIONS.

Reference to Fig. 11 shows the amount and distribution of rainfall * at different respective points in the state. The average rainfall for the state is 17.94 inches. Assuming that it takes 750 pounds of moisture to produce a ton of dry crop, upon the average, and assuming 15 per cent moisture in air-cured crops, the rainfall is sufficient to grow 3 tons of air-cured crop each year. Let us allow ourselves to use water extravagantly and assume but 50 per cent efficiency of all rainfall. If we were able to put 8½ inches of actual rainfall in our crop it would be expressed in wheat at the rate of 20 bushels per acre, which is about 8 bushels above the average yield of the state. If the yields in North Dakota are low it cannot be due to an absolute lack of water, but to the excessive use made of the water under present methods of farming. That this statement is well within the truth is indicated not only by the figures given, but by the isolated individuals scattered over the state who are securing much better yields than the average farmer.

Even the drouthy years evidently have not brought home to the farmers of North Dakota the fact that for them, **water** is the limiting factor in yields. By whatever name the facts and principles may be known, the North Dakota farmers of tomorrow must make it their immediate business to study sincerely and carefully those things that have to do with moisture conservation. The principles must be grasped and put into practice. When this is done the low yields so common at the present time will become things of the past. It should not be forgotten that there are some first class features associated with a reasonably low rainfall and one of the most important of these is the retention of fertility. The lack of winter rain fall and the absence of long continued leaching rains are beneficial in this regard rather than detrimental.

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*Some of the records go back to the early seventies. The duration of the records varies with the different stations.

In preparing this bulletin, free use was made of the information found in various books and station bulletins. In a bulletin of this sort it was not deemed advisable to give individual credit in each particular case. The following texts, among others, were frequently consulted: "Physics of Agriculture" and "Irrigation and Drainage" by F. H. King. "Soils" by E. W. Hilgard. "Dry Farming" by J. A. Widtsoe.

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NORTH DAKOTA AGRICULTURAL COLLEGE

North Dakota

GOVERNMENT AGRICULTURAL EXPERIMENT STATION OF NORTH DAKOTA

BULLETIN NO. 97

BARN PLANS

BY

R. M. DOLVE

Any farmer, teacher or student in the State may have this bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
MAY, 1912

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FOREWORD

There is abundant evidence that a radical change is being made in the methods of farming in North Dakota. A diversification of crops has resulted in the growing of corn, clover, barley and millet. This change in corp production makes the keeping of live stock a necessity as a menas of converting such farm crops into marketable commodities. Keeping live stock requires us to provide shelter, and the construction of barns for them represents a heavy outlay for a permanent improvement, which when once built cannot be easily or cheaply changed. Securing the best features in barns is largely a matter of the original design. Good types of them cost only a little more than ordinary ones—it is chiefly a matter of planning them right.

Uncomfortable and unhandy structures, not to mention unsanitary ones, collect their tolls in a lessened milk yield, a less thrifty colt, or a low egg producing flock of hens, ana in the course of the lifetime of the building cause an enormous loss.

Calls for barn plans have come to me regularly from the citizenship of the state. I feel therefore that a bulletin on barn plans is timely, that it will be serviceable, and that it will add materially to the chance of the changed system of farming becoming general and successful.

At my suggestion Prof. R. M. Dolve has prepared a rather wide range of plans of barns for different classes of live stock. He has in mind efficiency, convience and economy in addition to architectural form and an effective plan of construction.

Many inquiries from North Dakota farmers have called for rather extensive buildings constructed along modern lines and in response a few rather expensive types have been included. In general, however, the design has been to present effective usable plans which can be constructed upon either economical or elaborate lines to suit the conditions of the builder.

J. H. SHEPPERD.

INTRODUCTION

Although several of the plans shown in this bulletin are elaborate they are not meant to convey the impression that expensive structures are essential to the proper housing of farm animals, but to point out a few principles that are of general application and to indicate what is sanitary, convenient and modern in barn construction. The designs are intended to be suggestive rather than specific and with this in view the plans are so arranged as to be susceptible of almost numberless variations and combinations to suit individual requirements and yet include the points of excellence the several plans possess. For this reason none of the plans are complete as to every detail and no figures are given on bills of lumber, cost and other specifications usually accompanying the complete working plan of any structure of importance.

While it is not the writer's wish to induce farmers to put large sums of money into buildings, this bulletin is intended to emphaszie the fact that it pays to build well and that the buildings should be carefully planned and every detail well worked out before building operations are commenced. Although it is believed that every plan submitted is thoroughly practical it should be carefully adapted to the requirements of the particular farm before it is adopted. The farmer who contemplates building should look upon it as an investment and should so build that his investment will be a profitable one. He should look upon his barn as a factory wherein he converts his feed stuffs into butter, beef, bacon or eggs as the case may be and should endeavor to so arrange every detail that the best results may be attained from the feed consumed and labor expended. If this view is maintained he will give more attention, not only to economy and convenience but to such vital questions as heat, light and ventilation which are usually so badly neglected in barn construction.

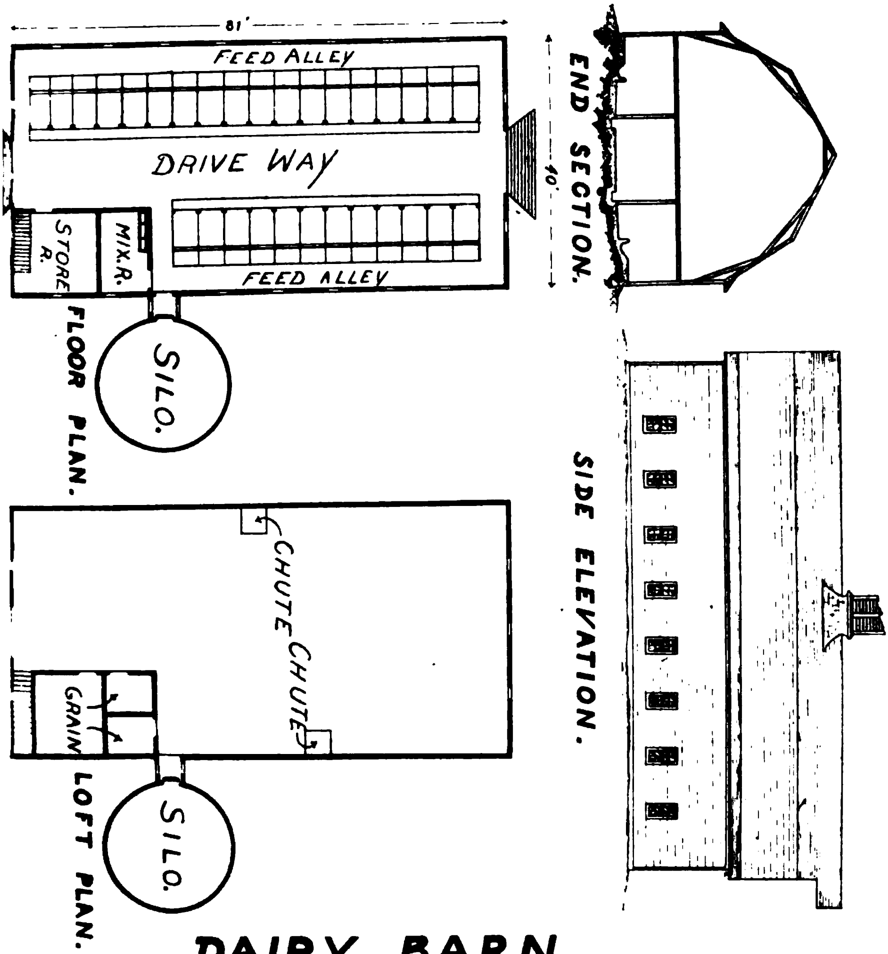
Beauty and attractiveness of design should not be lost sight of, for it is conductive to happiness and contentment and has a refining influence incompatible with ugly buildings and incongruous surroundings. Any reasonable amount of money expended in this direction is well invested, for it adds to the desirability of farm life and is a mighty factor in ennobling the farmer's calling in the estimation of the world and especially in the eyes of the young boy who is too often driven away from the farm by an unattractive and unsympathetic environment.

The writer does not claim originality for all the plans presented in this bulletin. Ideas have been gathered from a variety of sources and whatever has been deemed good in buildings and plans already devised has been incorporated in an effort to make the designs thoroughly practical and to enable the farmer to take advantage of the experience of others.

DAIRY BARN

Plates No. 1 and 2.

Plates 1 and 2 illustrate a dairy barn accomodating 30 cows. The stables are arranged in two rows with the cows facing out or towards the side walls. The feeding alleys in front of the mangers are four feet wide and each one is provided with a centrally located hay chute (see loft plan) which makes the feeding of hay a simple operation. For greater convenience in handling grain and silage, feed car-



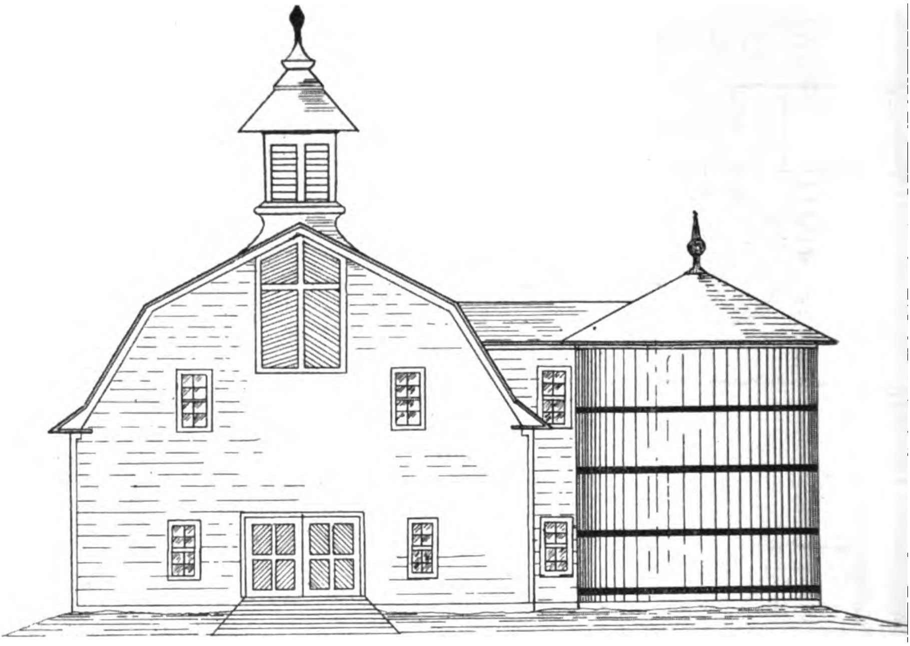
DAIRY BARN.

PLATE NO. 1

riers with a track extending into the mixing room and to the silo may be provided.

The stalls, mangers, gutters, etc. may be of any approved size and construction—see description of stalls, page 49.

The driveway is 10 feet wide between the gutters giving ample width for driving through with a large manure spreader or wagon. This arrangement makes cleaning the barn very convenient and this plan is preferred by a great many dairymen on that account.



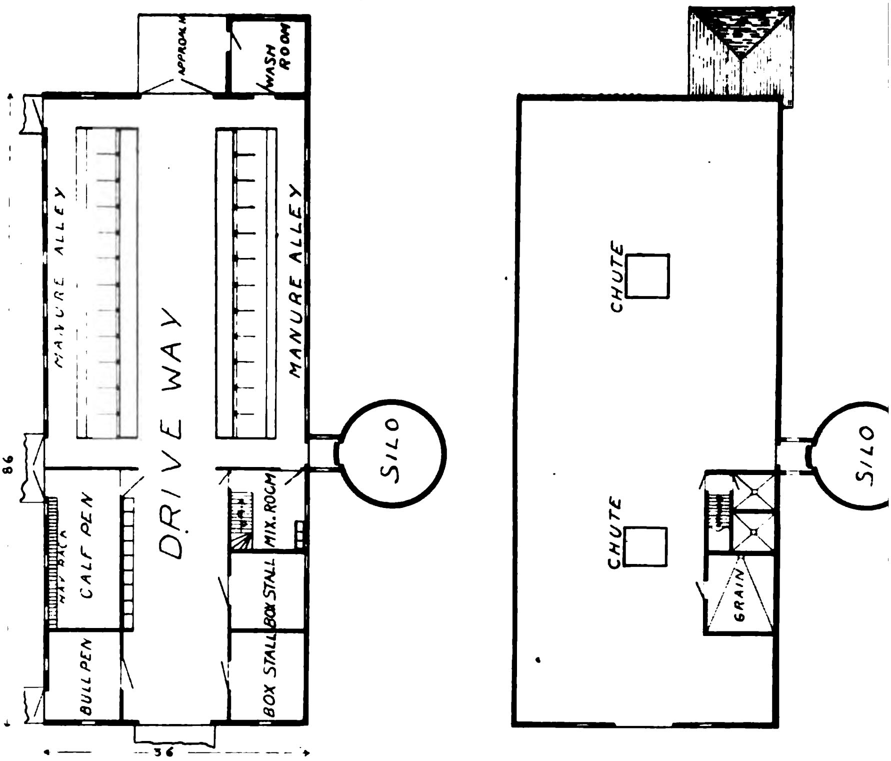
FRONT ELEVATION
DAIRY BARN
PLATE NO 2

The store room or mixing room should be provided with sinks and lavatories in which the men may wash their hands and utensils. This room is placed immediately below the grain bins so that the grain may be spouted directly into the mixing troughs shown in the floor plan.

The silo as shown is of the stave type 20 feet in diameter by 24 feet in depth with an approximate capacity of 135 tons.

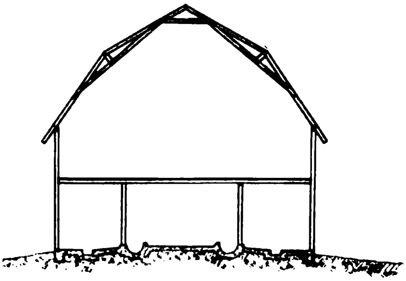
The barn is of the curb roof type which gives ample space for hay. As many curb roofed barns have been built with a weak and defective roof construction, particular attention is called to the method of bracing the roof as shown in the illustration of an end section.

The stable room is 9 feet high but the height may be varied to suit climatic conditions—some dairymen prefer lower ceilings in cold climates. The posts are 16 feet high and the total height of the barn is 34 1-2 feet. The hay mow will hold approximately 100 tons of hay when filled to the break in the curb roof.



FLOOR PLAN

LOFT PLAN



END SECTION

DAIRY BARN

PLATE NO 3

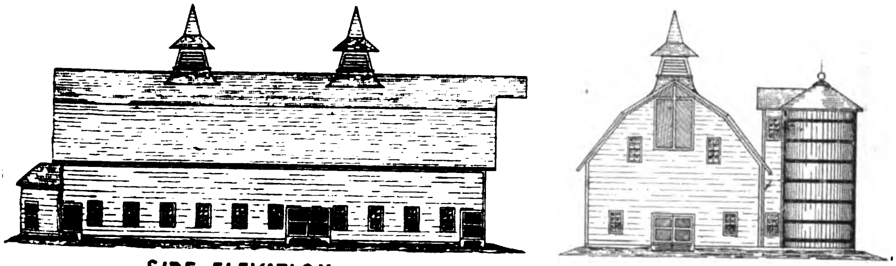
SCALE IN FEET

DAIRY BARN

Plates No. 3 and 4.

Plates 3 and 4 show a dairy barn with a curb roof construction having 16 foot posts and an extreme height of 35 feet, a length of 86 feet and a width of 36 feet. The hay mow will hold approximately 90 tons of hay.

This barn accomodates 24 cows in stalls and in addition has a calf pen 10 by 22 feet, a bull pen 10 by 12 feet, two box stalls each 10 by 12 feet and a 10 by 10 foot mixing room which contains a stairway leading to the loft. A 10 by 10 wash room may be built on the rear of the barn as shown in the plan. This barn shows the cows facing a 10 foot driveway through which provender may be hauled. The manure alleys are 4 feet in width from the gutter to the wall and should be provided with manure carriers running on tracks.


SIDE ELEVATION

FRONT ELEVATION

DAIRY BARN

PLATE NO 4

SCALE IN FEET

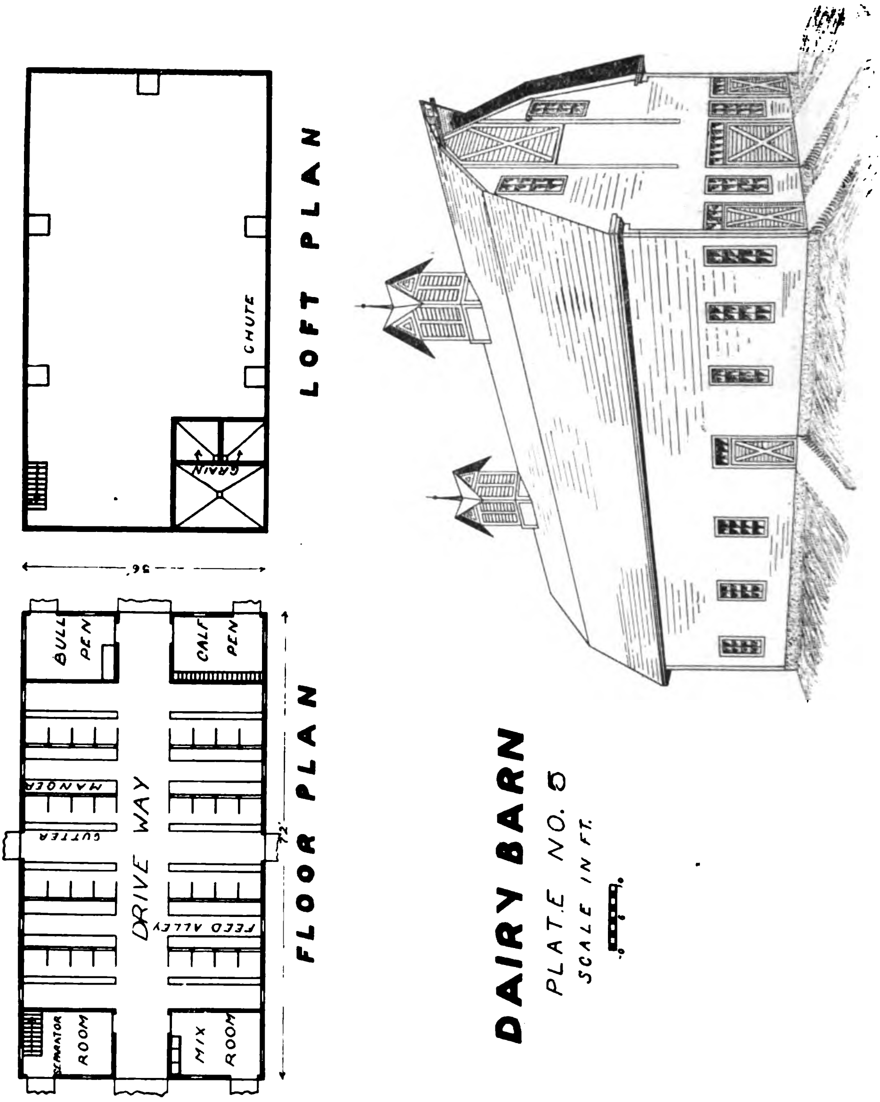
The silo is 15 feet in diameter and 30 feet in depth, the floor extending 2 feet below the ground line. It will hold approximately 105 tons of silage.

DAIRY BARN

Plate No. 5

Plate 5 illustrates a dairy barn 72 by 36 feet in dimension with a curb roof and hay mow of 75 tons capacity.

The barn accomodates 32 milch cows in stalls and con-



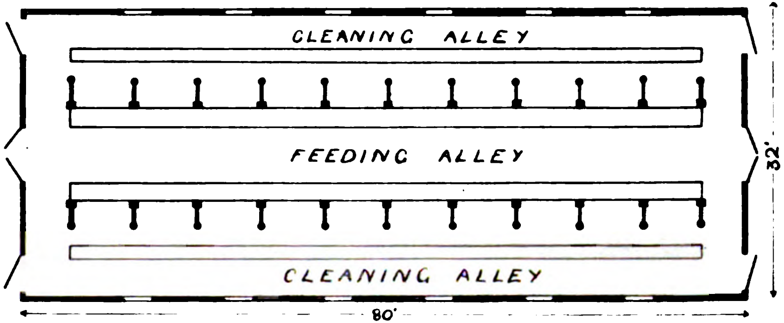
DAIRY BARN
PLATE NO. 5

tains a calf pen, bull pen, mixing room and separator room each approximately 12 by 14 feet.

The arrangement of the stalls is somewhat different from the ordinary plan but it has a decided advantage in that the light from the windows in each alley is unobstructed by the stall partitions and the bodies of the animals. By this arrangement better light may be secured throughout the entire barn than by any other method.

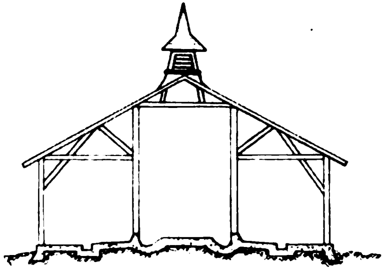
No silo is shown in the drawings but if one is desired it may be conveniently located so that its feed chute opens into the mixing room or it may be placed so as to open into one of the feed alleys on one side of the barn.

As shown in the loft plan feed chutes are provided for each alley thus making the feeding of hay and the distribution of bedding from the loft convenient.



FLOOR PLAN

SCALE IN FT.



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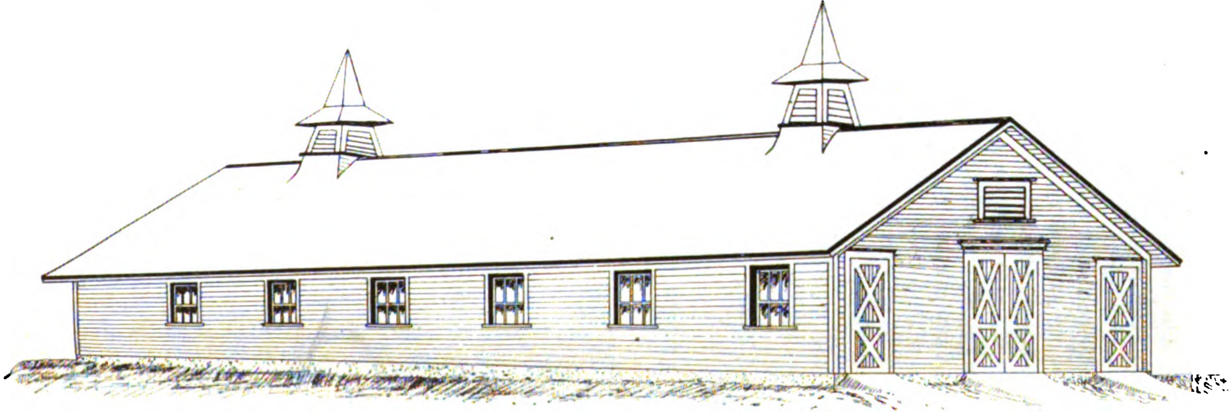


BARN FOR BEEF CATTLE

PLATE NO. 4

BARN FOR BEEF CATTLE

Plate No. 6.

The barn illustrated in plate 6 is 32 by 80 feet and will accomodate 40 beef cattle in double stalls. Double stalls are considered best for beef animals by most cattle raisers.

The barn has 10 foot posts and is 18 feet high to the pitch of the roof. No room is provided for storing hay and feed but if an overhead hay mow is desired a curb roof may be put on and the height of the posts increased to insure the desired capacity.

A feeding alley 6 feet wide is provided through the middle of the barn so that rough feed and grain may be distributed directly from a wagon hauled through the barn. The doors opening into the feeding alley are of ample width and height to accomodate a large load of hay. Attention is called to the frame construction shown in the end section. The design is such as to not only throughly brace the structure but the construction is such that no timbers are in the way when unloading.

The barn is provided with exceptionally large windows insuring sufficient light on dark winter days.

The floor is of concrete with mangers and gutters cast in the floor as shown in the end section. See stalls page 14. The driveway is raised well above the stall and alley floors so as to allow deep mangers without a retaining wall above the level of the driveway. This makes cleaning the mangers and driveway easy and convenient.

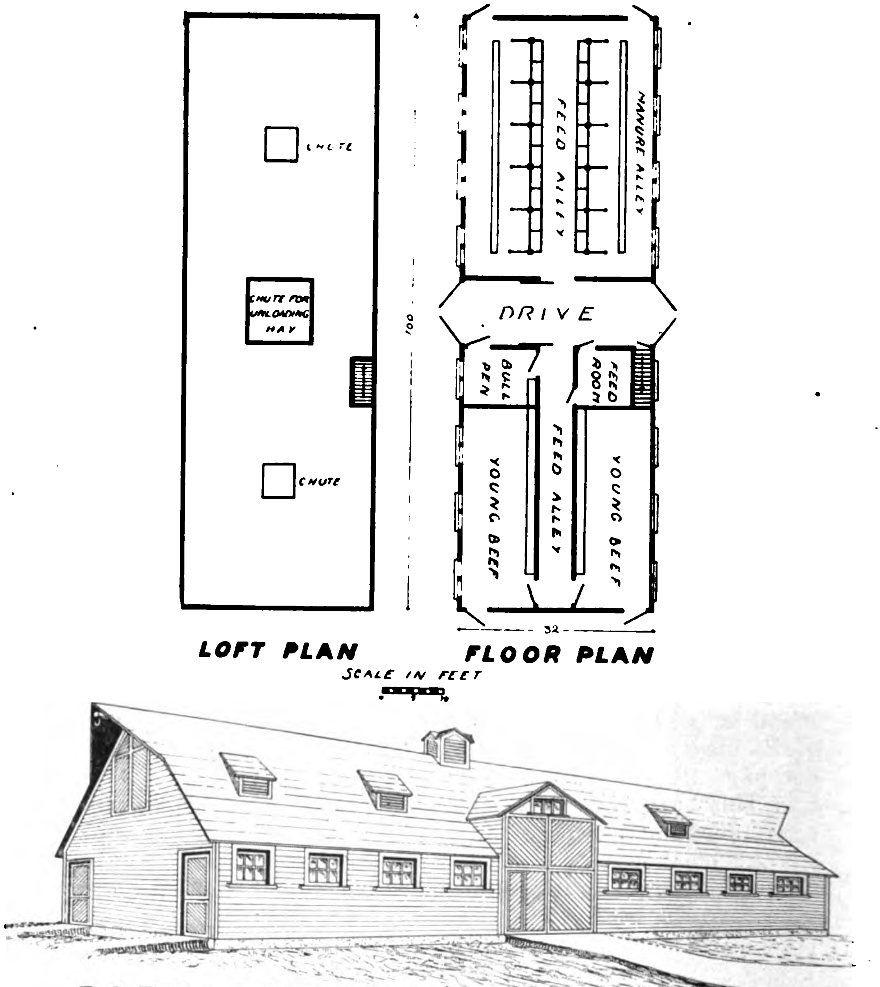
The stalls are of the iron pipe form set in concrete. No wood is used in the construction and the entire floor and stalls may be flushed out with a hose. For detail of stalls see page 49.

This barn is especially designated for farms where separate sheds are used for young beef stock but the interior arrangement may be altered to contain pens for young beef stock if desired. It is a handsome, convenient and inexpensive barn for beef cattle.

BARN FOR BEEF CATTLE.

Plate No. 7.

Plate 7 represents a modern and up-to-date though inexpensive barn for beef cattle. It has a large roomy loft in which considerable hay may be stored. The hay may be taken in at either end or up through the large chute over the central driveway. This provision for unloading inside



BARN FOR BEEF CATTLE
PLATE NO. 7

will be found very convenient on stormy winter days. This chute may also be used as a feed chute when desired. The central driveway may be closed up and used as a stock pen, without material inconvenience, when the barn is crowded.

The structure is 32 by 100 feet with room for 20 animals in double stalls in one half of the barn and accomodations for a larger number of young stock in two large pens in the other half. A feed room and bull pen each 9 by 12 feet is also provided.

The central feed alley is 5 1-2 feet wide while the manure alleys are 4 1-2 feet wide. The manure carriers may easily be arranged to dump into a wagon or spreader in the central driveway.

The barn is well lighted and ventilated and is a practical and convenient design for beef cattle.

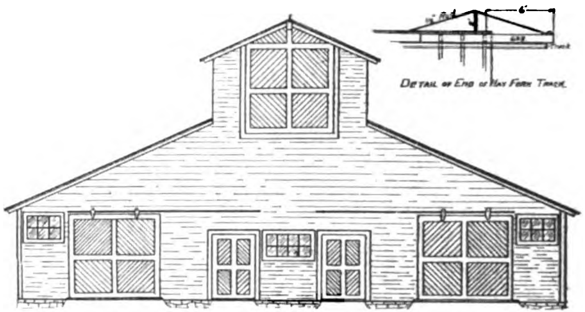
FEEDING SHED FOR BEEF CATTLE

Plates No. 8 and 9.

The ranching industry of the West is rapidly passing and it is only a matter of time until the districts still regarded as fit only for grazing will, through modern methods of dry farming or irrigation, be brought under cultivation. This means that a constantly increasing portion of the beef consumed must be farm fed and, as feeders have learned that the most economical and satisfactory way of feeding cattle for the market is in large sheds where they are permitted to run loose, there will be a constantly increasing demand for shed plans. These sheds should be as convenient as possible so as to reduce the cost of labor to a minimum and yet be economical in first cost, durable and sanitary. Although in the design shown in plates 8 and 9 special emphasis has been placed on convenience, it is believed that the other requirements have not been overlooked. This shed is 50 by 80 feet and will accomodate seventy head of cattle. The space for cattle is divided by the central feed alleys into two parts, each 18 by 80 feet. The middle of the shed is devoted to a feed bin 6 feet in width and extending the entire length of the shed. The feed bin is filled through the windows at either end. The feeding of grain is exceptionally convenient and is accomplished by dipping a shovel or feed measure into the side of the bin and depositing it into the feed troughs on the other side of the alleys. The openings in the side of the bin run the entire length of the barn and should be ample in size to allow a man to dip grain from the bottom of the bin. The

FEEDING SHED FOR BEEF CATTLE

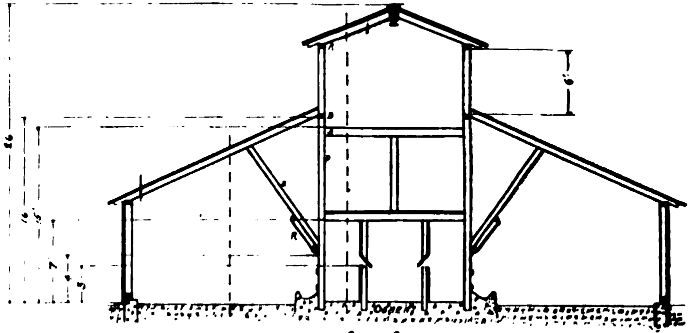
PLATE No 8



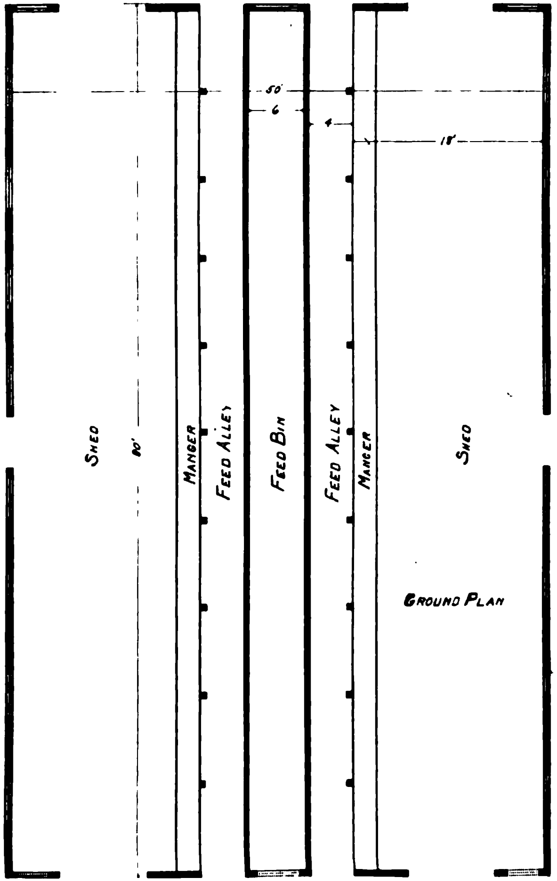
DETAIL OF END OF HAY FORK TRACK.

END ELEVATION

SCALE IN FEET

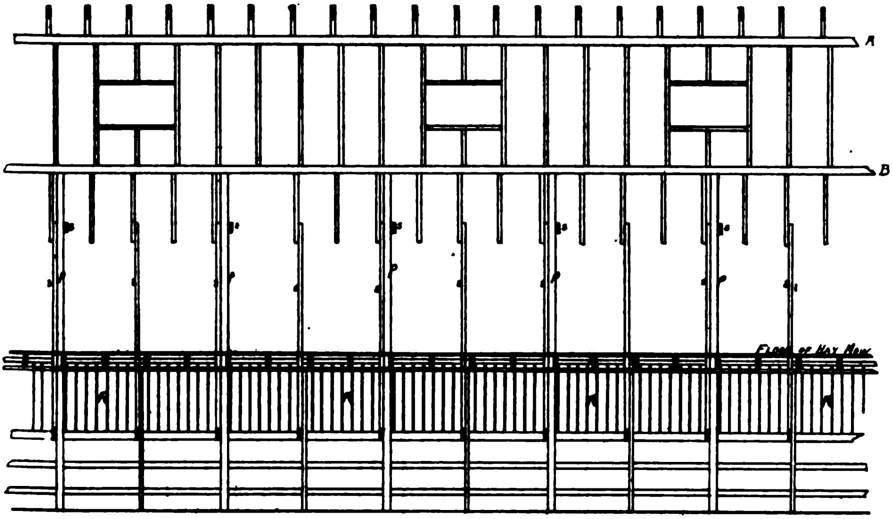


CROSS SECTION



GROUND PLAN

PLATE No. 9

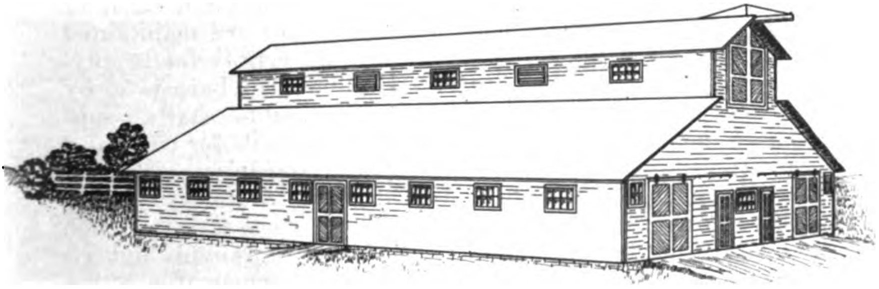


SIDE ELEVATION OF FRAMING BETWEEN DOTTED LINES ON CROSS SECTION

S - TIES ACROSS MOW   F - FEED RACK SUPPORTS   P - POSTS   R - FEED RACK

A & B - PLATES. SEE CROSS SECTION.

0 5 10
SCALE



PERSPECTIVE OF FEEDING SHED

openings are protected by a slanting board so arranged that the bin may be filled without grain spilling through the openings. The bin and alleys are 7 feet in height and have a concrete floor while the rest of the floor is earth.

The plan for feeding the hay is also convenient. When the hay mow is filled the hay will rest on the inclined rack supports A (see cross section illustrated in plan) and as the cattle feed from the racks R the hay will slide down automatically refilling them. When enough hay has been eaten away to prevent the filling of the racks, a supply may be pitched onto them in a few minutes, which will last for several days. The racks are made from five eights inch round iron bars and should be placed close enough together to prevent the wasting of hay.

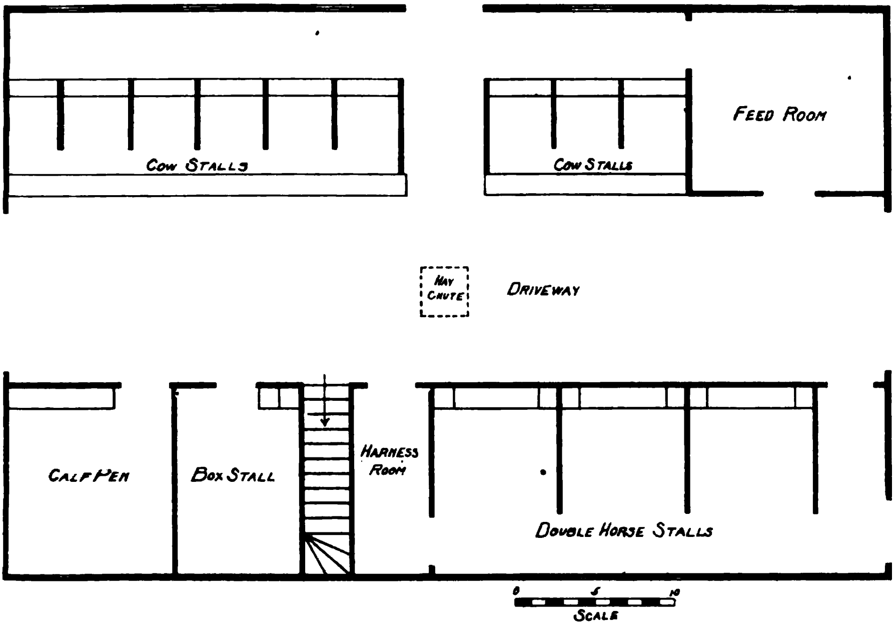
Large sliding doors are provided at both ends of the shed so that a wagon loaded with straw or a manure spreader may be hauled through. The shed is well lighted by large windows placed high enough on the wall to prevent them from being broken by the cattle. Four louveres are placed in the top of the shed for ventilation. The roof is supported by two rows of posts P placed along the outside of the feed alleys. The posts are 8 feet apart with cross ties and supports S between each pair of posts to securely brace the building. This will be found a practical and convenient shed embodying many desirable features which it is believed the drawings will make sufficiently clear without further explanation.

HORSE AND CATTLE BARN.

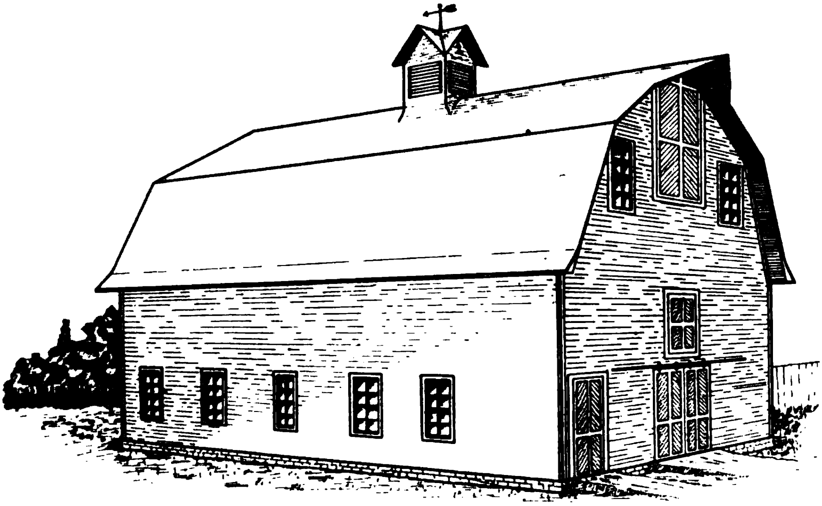
Plate No. 10.

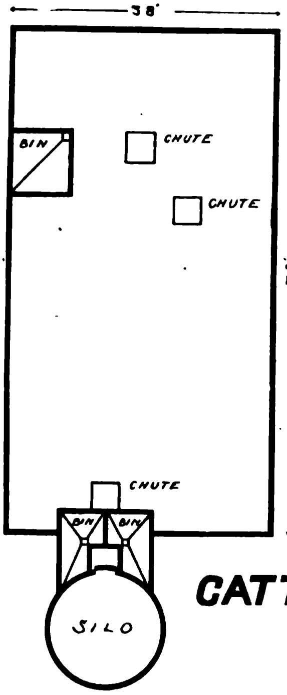
Plate 10 shows a barn intended for a grain farm of about 160 acres where only enough horses are maintained to do the farm work and cattle are kept mainly for supplying the household with butter and milk. The barn is 36 by 56 feet and accomodates six horses in double stalls, supplies a box stall 8 by 12 feet, nine single stalls for cows and a calf pen 10 by 12 feet. The ground plan also contains a feed room 15 by 16 feet. An 11 foot driveway passes through the center of the barn. The structure has a curb roof with large storage space for hay; is thoroughly lighted and ventilated and is well suited to the purpose for which it is designed.

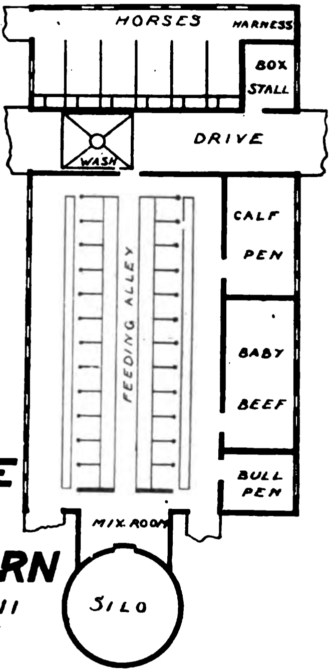
PLATE No 10



HORSE AND CATTLE BARN





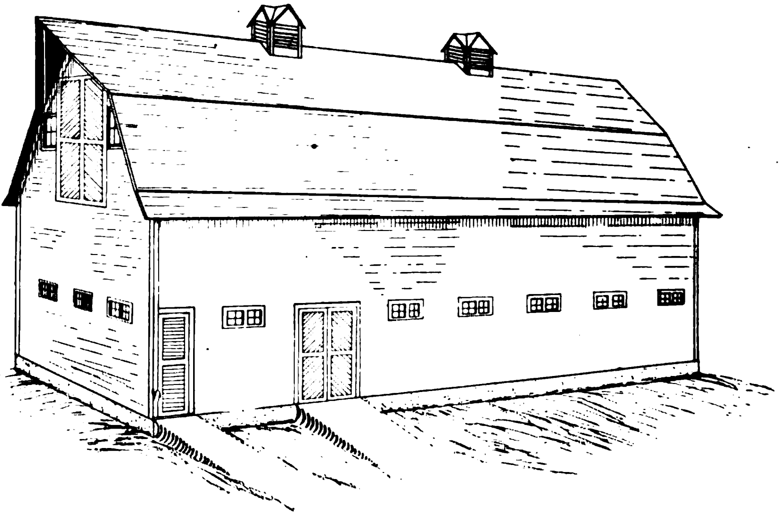


HORSE & CATTLE BARN

PLATE NO. 11

SCALE IN FT.

0 5 10



HORSE AND CATTLE BARN

Plate No. 11.

The idea of the design illustrated in plate 11 is to show a barn thoroughly modern and convenient and one which is as compact and economical as possible.

The barn is 38 by 72 feet and, considering its many convenient features, accomodates a large number of animals without being crowded. The plan provides room for 24 cows in stalls, a 9 by 21 feet pen for young beef, a 9 by 16 feet calf pen and a 9 by 9 feet bull pen.

The horse stable has room for six horses in ample single stalls and one 7 by 9 feet box stall with door opening into the driveway. A small harness room is provided at the back of the box stall.

A place for washing buggies and animals is provided in the driveway. This is a feature that should be found in every horse barn. The wash floor slopes to a central drain.

The barn is provided with ample feed bins coveniently located also convenient hay chutes.

The structure is designed with a curb roof which is considered the most economical where an overhead hay mow is desired.

The silo is conveniently located and may be built any size dependent upon the number of days in the year silage is to be fed to the stock.

This is a practical construction and should appeal to any one desiring a convenient, but inexpensive combination barn of moderate size.

HORSE AND CATTLE BARN

Plates No. 12, 13, 14, and 15.

Owing to the extreme levelness of a large portion of the state bank barns are not practical on every farm but they are very desirable when properly constructed in a suitable location. Before a bank barn is built evidence should be secured that the bank is at all times of the year dry and well drained to the depth that it is desired to place the basement. This precaution seems necessary on account of the musty dampness that prevails in the basement of many bank barns. Another objection to most bank barns is that the basement has insufficient light and ventilation. These objections can all be overcome by planning the barn properly and using the right material in its construction, but, if they cannot be eliminated, it is far better to build a barn above ground and to forego the conveniences and

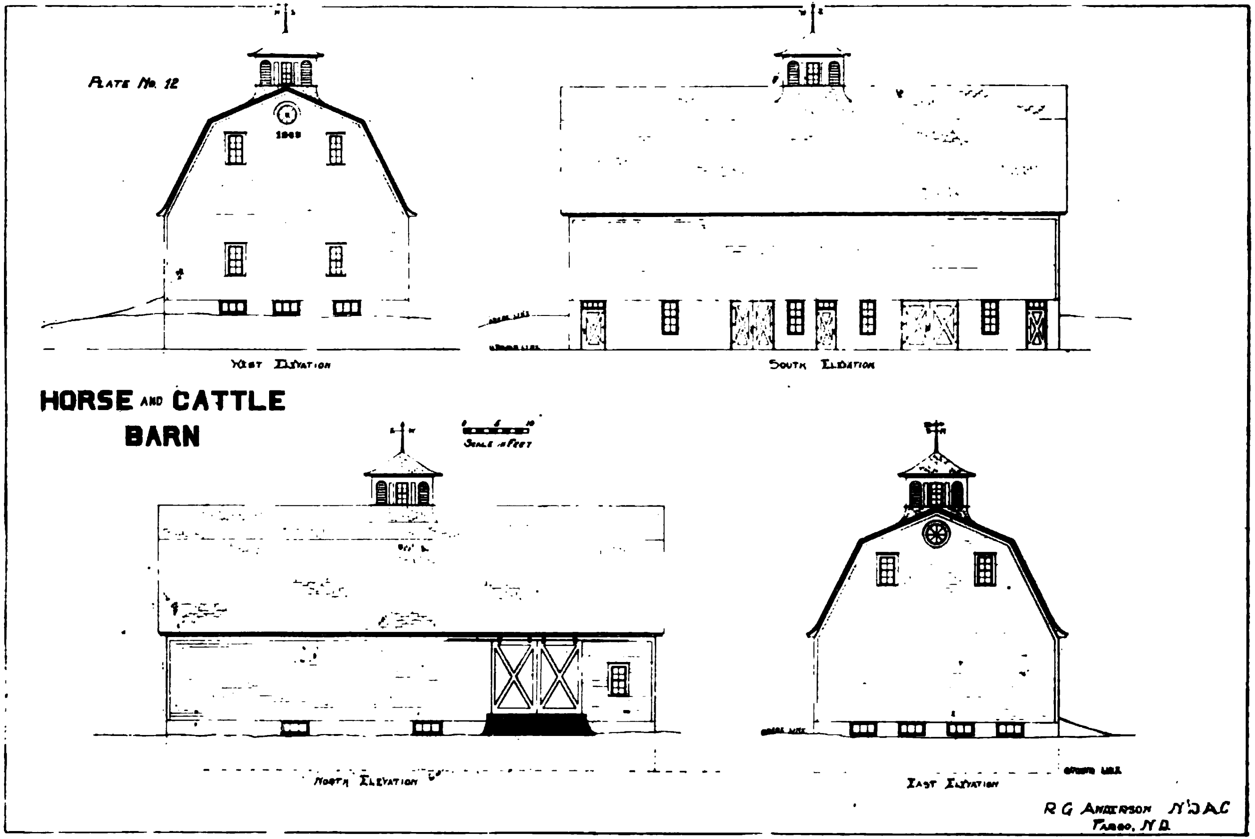


PLATE No. 12

HORSE AND CATTLE BARN

R G Anderson N.D.A.C.
Fargo, N.D.

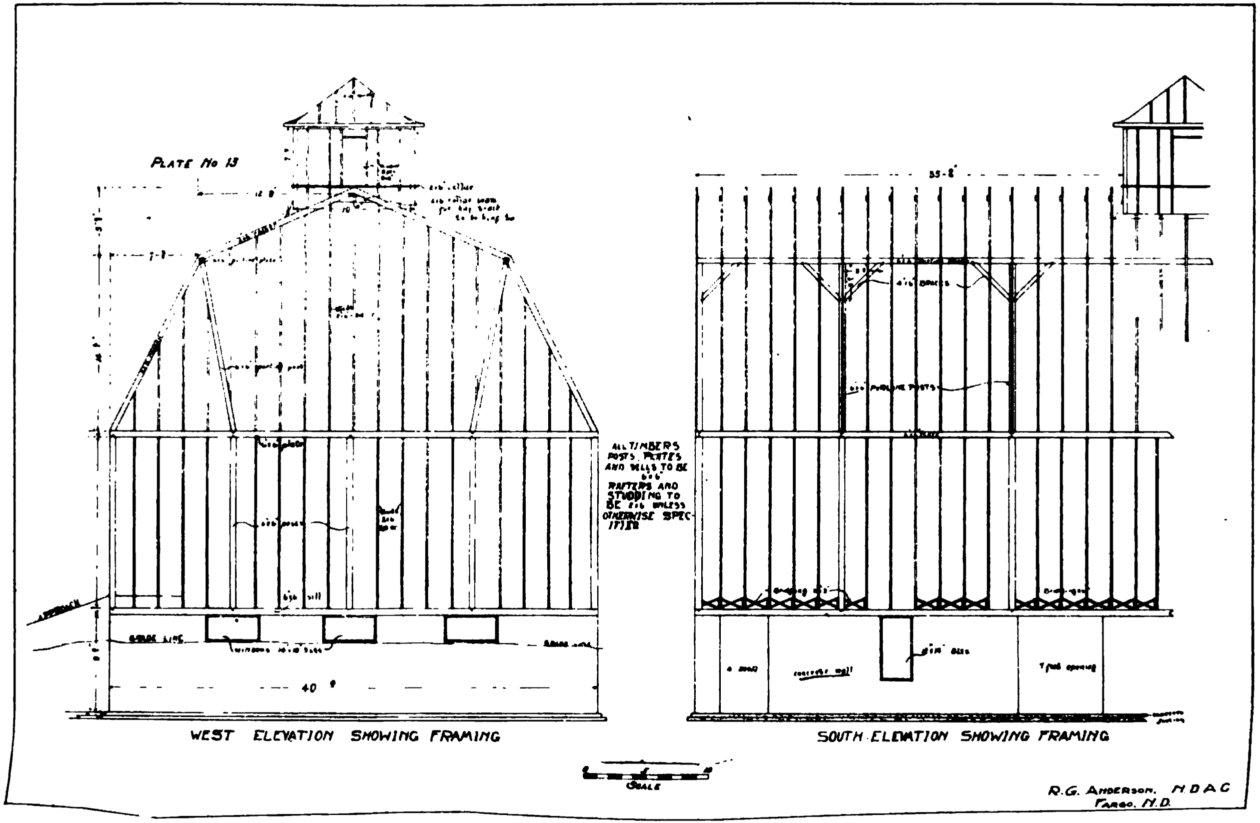
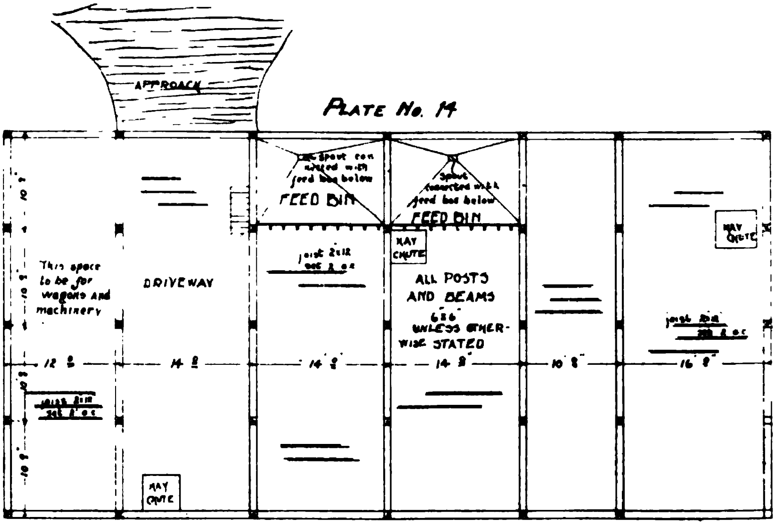


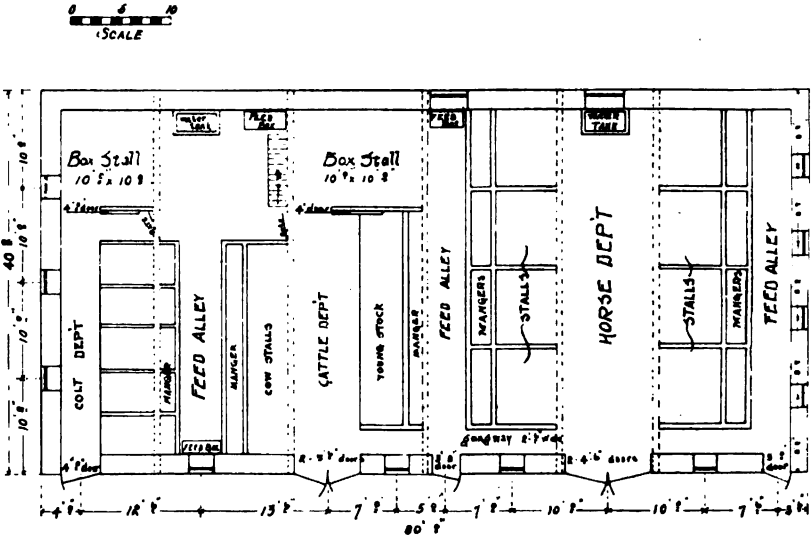
PLATE No 13
12 8
55-8
APPROACH
GRADE LINE
6x6 sill
40 0
ALL TIMBERS POSTS, PLATES AND SILLS TO BE 6x6 RAFTERS AND STUDDING TO BE 2x6 UNLESS OTHERWISE SPECIFIED
concrete wall
7 foot opening
WEST ELEVATION SHOWING FRAMING
SOUTH ELEVATION SHOWING FRAMING
SCALE
R.G. ANDERSON, N.D.A.C.
FARGO, N.D.

economy of a bank barn rather than have it deficient in these respects.

PLATE NO. 14


APPROACH
Spout connected with feed box below
FEED BIN
Spout connected with feed box below
FEED BIN
HAY CHUTE
joist 2x12 set 2' o.c.
ALL POSTS AND BEAMS 6x6 UNLESS OTHERWISE STATED
This space to be for wagons and machinery
DRIVEWAY
HAY CHUTE
joist 2x12 set 2' o.c.
joist 2x12 set 2' o.c.
10'
10'
10'
12'
14'
14'
14'
10'
16'
HAY CHUTE

PLAN OF FIRST FLOOR
Showing girders and posts in place.

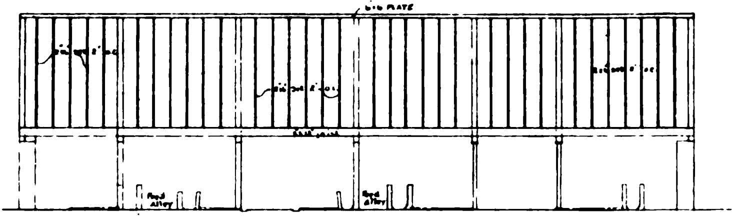


BASEMENT PLAN

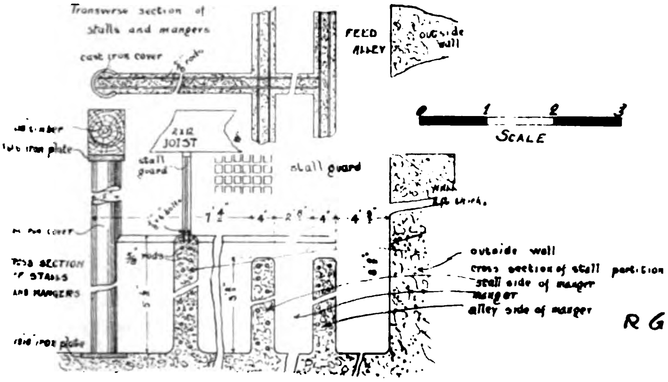
R.G. ANDERSON, N.D.A.C.
FARGO, N.D.

The bank barn illustrated in these plates is 40 feet wide by 80 feet long with a full size basement 8 1-2 feet in the clear with concrete walls and floor. The barn is placed sideways to the bank so that the basement floor is about 6 feet below the bank surface on one side and both ends, while the other side (see south elevation) projects out of the bank to the level of the basement floor. The north elevation is provided with large sliding doors through which a load may be driven upon the first floor. This makes the unloading of feed into the bins very convenient.

PLATE No. 15



LONGITUDINAL SECTION



DETAIL AND CROSS SECTION
OF STALLS AND MANGERS
IN HORSE DEP'T.

R G ANDERSON N.D.A.C
FARGO N D.

The basement is partitioned off into stables for ten horses in double stalls, two 10 by 10 feet box stalls, five single stalls for colts or young horses, six cows in single stalls and ten head of young stock in stanchions.

The detail and cross-section of stalls and mangers are shown in plate 15. The stall partitions are made of reinforced concrete and in the horse department they extend to a height of five and one half feet with an iron grating or stall guard extending to the ceiling. The ends of the stall partitions are protected from chipping by cast iron posts with a slot cut in them to receive the end of the concrete stall partition. These posts also serve as supports for the floor overhead. No wooden constructions whatever are employed in the basement, concrete being used exclusively with the exception of the cast iron posts and stall guards.

The first floor is 8 feet in the clear and is designed for the storage of feed, wagons, carriages and all farm machinery which may be conveniently hauled in through the 14 foot doorway in the north elevation. All the posts and braces on this floor are to be placed directly above those of the basement floor and, since barns of this description are often built with insufficient bracing special attention is called to the elevations showing the details of framing.

The hay mow has a capacity of 120 tons of hay which is fed to the basement floor through chutes conveniently arranged above the feed alleys.

The barn is well lighted and convenient in all appointments but the interior arrangement may be readily altered without affecting the general construction.

The King system of ventilation, (see page 53), if properly installed, will work perfectly in a basement barn both because of the airtight walls and the great height of the structure.

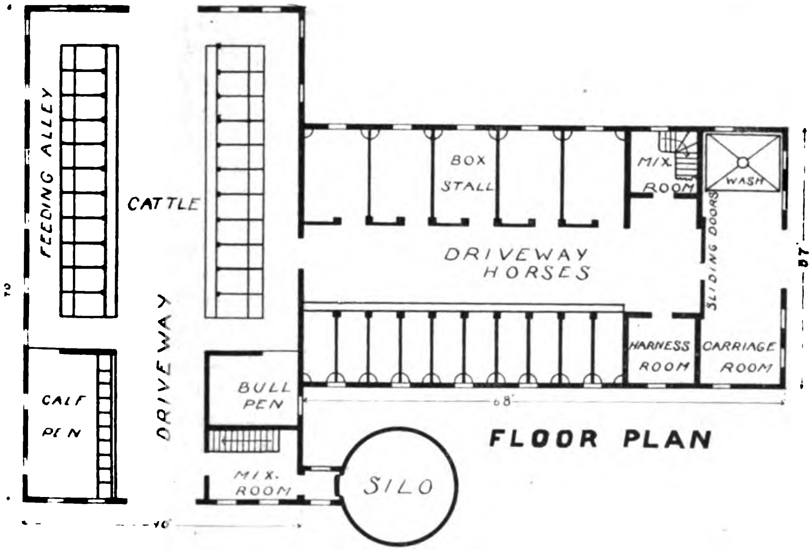
HORSE AND CATTLE BARN

Plates No. 16 and 17.

Although these plates shown as No. 16 and 17 represent a design which is elaborate it is not beyond the reach of many farmers who desire a beautiful as well as modern barn. It is well ventilated and roomy though economical of space.

The cattle department is 40 by 70 feet with accommodations for 22 cows in stalls together with large calf and bull pens. The feeding chute of the silo opens into the mixing room so that the feed and silage may be distributed throughout the barn with the minimum amount of labor. The ample driveway through the center permits driving through the barn with a manure spreader or loaded hay wagon.

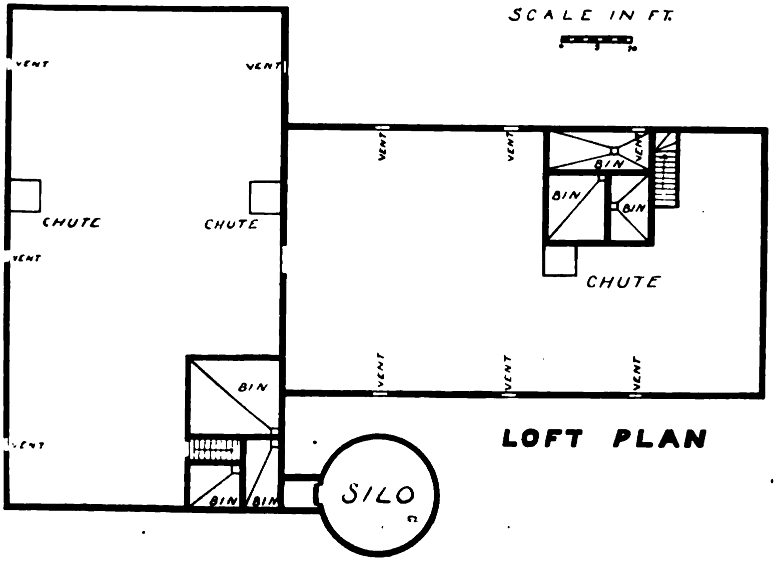
The horse department is 37 by 68 feet giving room for 10 horses in single stalls besides five 8 1-2 by 13 feet box stalls. The barn further contains a 9 by 9 feet mixing room, a 9 by 9 feet harness room and a 37 by'11 feet wash and carriage room. A central driveway similar to the one



HORSE & CATTLE BARN

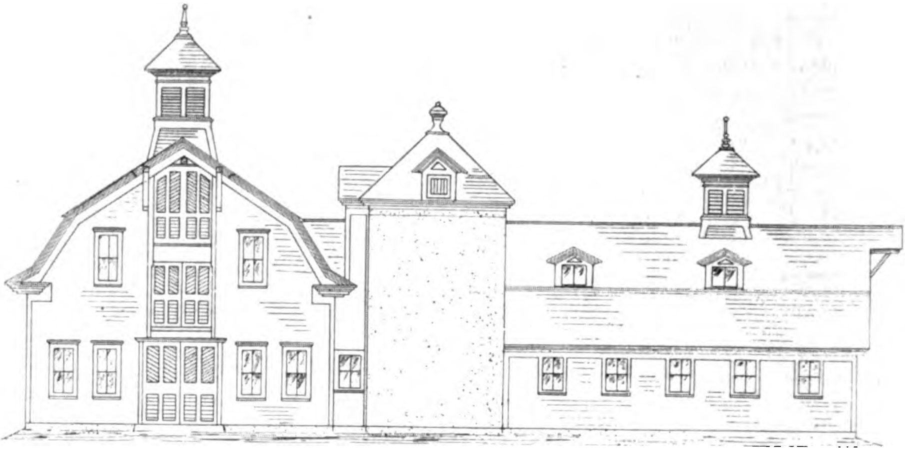
PLATE NO 16

SCALE IN FT.

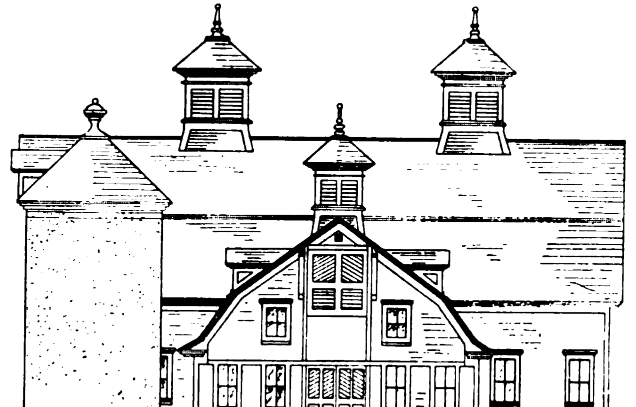


in the cow stable is provided here.

Corner racks of iron bars are provided in lieu of mangers, each stall has an individual hay chute from the loft. The central hay chute may be used if desired but is provided especially for removing litter and bedding from the loft.



SIDE ELEVATION



FRONT ELEVATION

PLATE NO. 17

SCALE IN FT.

HORSE BARNS

Plate No. 18.

On the great majority of farms we find a single structure accomodating both horses and cattle. This plan is usually the best and most economical type of construction on small farms where but comparatively few horses and cattle are kept and is not objectionable where one department or division is provided for horses and another for cattle so that they occupy distinctly separate parts of the building. On the larger farms, on the other hand, a single structure for both horses and cattle assumes such vast proportions that it will cost but little more to erect two separate buildings and often an actual saving in first cost is effected. Although the construction of good, serviceable combination barns where they meet the requirements is not to be disparaged, their adaptability too often resembles that of the combination tool designed to take the place of several distinct appliances with the usual result that it is a makeshift not well adapted for any purpose. Then, too, the danger of loss from fire, lightning and storms is emminent enough to make separate buildings desirable.

Too often horses are confined in low, dark and damp buildings more resembling dungeons than stables. A horse shut up in a place deficient in light and ventilation can no more be expected to come out fresh and eager for work and motion than a human being under similar circumstances. Horses require light, airy and dry shelter and are too valuable to be housed in buildings deficient in this respect. The prospective builder should, therefore, carefully plan a barn that will not only meet his requirements as to size and convenience but he should also give due regard to the comfort and well-being of the horses to be sheltered.

A separate harness room will be found well nigh indispensable in an otherwise well arranged barn and a carriage room, separated from other departments of the barn by doors so that dust may be excluded is a great convenience. This room should have a sloping space in the floor with a good drain where carriages and animals may be washed and cleaned. Ample provision should be made for the storage of hay, ground feed and oats. These features are all embodied in this plan as shown.

The main part of the horse barn presented in plate 18 is 50 feet long and 36 feet wide while the wing partly containing the carriage room has a 20 foot front and is 16 feet in depth. This barn accomodates 10 horses in single stalls 5 feet wide besides three box stalls 8 by 13 feet for drivers

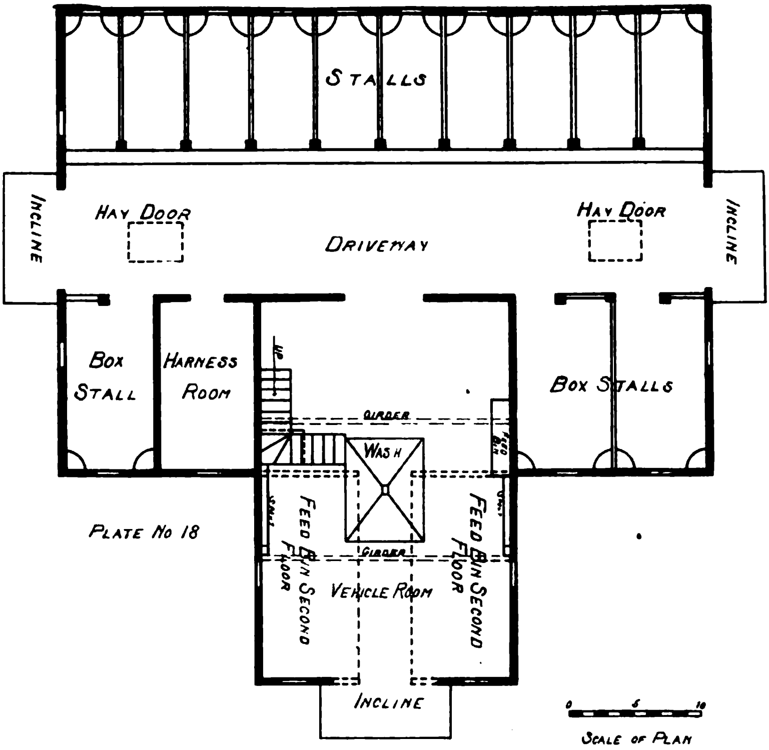
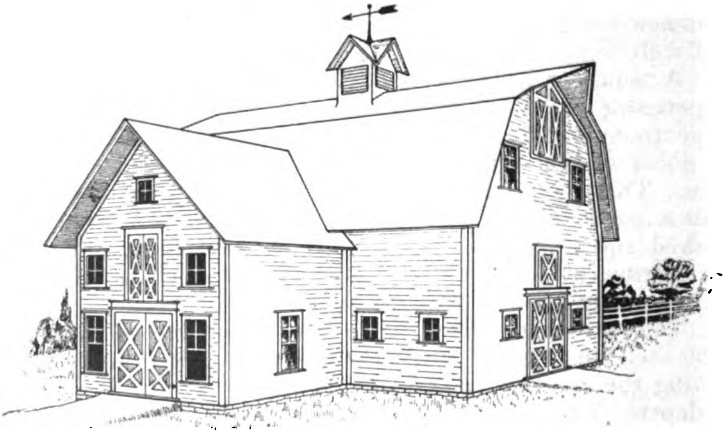


PLATE NO 18

HORSE BARN



or brood mares and a harness room of the same dimension. A driveway 12 feet in width passes through the center of the barn from end to end and is not only intended to be wide enough for a manure spreader or load but is for the purpose of providing that roomy airiness so desirable in a horse barn.

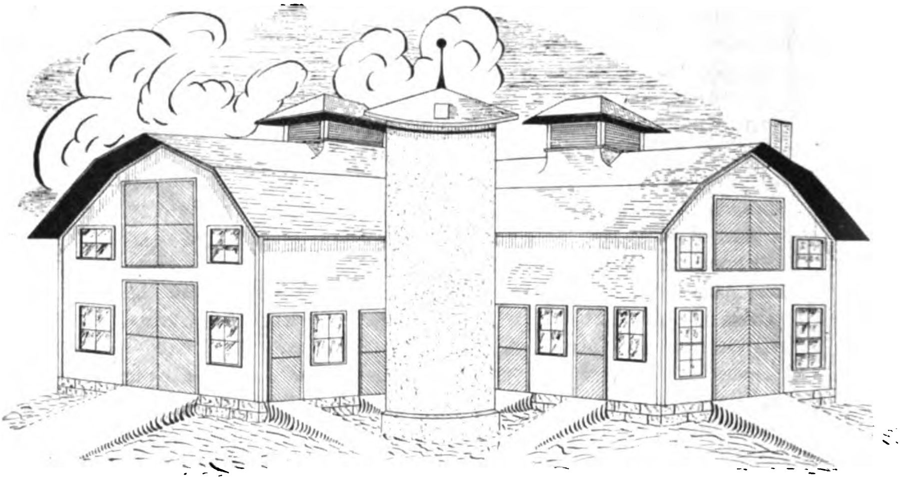
Abundant light is secured in every part of the barn by providing one window for every stall. The barn is ventilated by the King system—page 53. The ideal way of housing horses is in box stalls but they require about three times as much room as single stalls and are, for that reason, provided only for the carriage horses. A box stall should be strong and well lighted; the walls should be smooth so that the animals connot rub their tails or manes. Many builders place a two by six on edge horizontally against the wall below the height of the mane and tail of the horse. This will prevent the horse from rubbing himself against the walls. The edges of the plank should be smooth and rounded. The door of the box stall should be cut into halves so that the upper portion may be left open during the day to permit the horse to look out. This makes the stall less of a prison and makes the animal more agreeable. The stalls are provided with iron corner racks for hay and feed with shallow mangers beneath to prevent waste. The feeding of hay is done from the loft through small individual chutes for each stall.

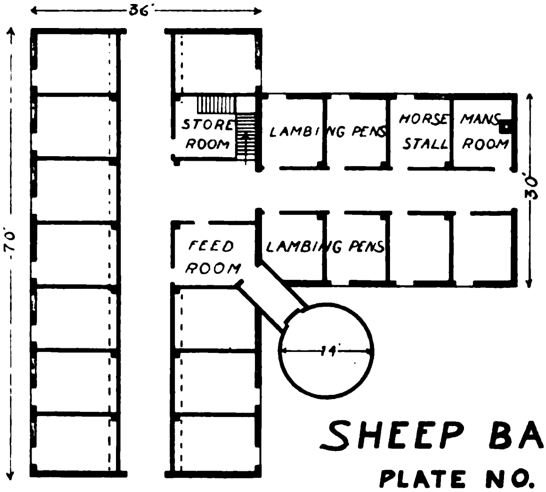
The vehicle room is 30 by 20 feet and besides furnishing sufficient room for a reasonable number of carriages contains a concrete wash floor and the loft stairway. The loft over the vehicle room is devoted to the storage of feed and has a central alley between the bins. The feed is spouted into two small feed bins on the ground floor, one located under the stairway and the other along the opposite wall.

SHEEP BARN

Plate No. 19.

The gradual breaking up of the great ranches of the west through the encroachments of the settler has made sheep raising on the farm highly profitable. Many grain farmers are realizing that there is good money in sheep raising when intelligently managed. The greatest loss in sheep raising on a small scale is apt to occur during the lambing season and a well planned sheep barn should be arranged to guard against that contingency. The accompanying plan provides for a man's room in which should be found a stove so that a man may sleep there during the lambing season. Weak lambs can usually be saved during the coldest weather if artificial heat can be provided for a few hours. A horse stall is also provided but this can be





SHEEP BARN

PLATE NO. 19

FLOOR PLAN

SCALE IN FEET

utilized as a pen if the barn is located in the vicinity of a horse barn. Separate pens are provided into which the ewes are placed during the lambing season after which these enclosures may be used as regular feeding pens. The lambing pens should have a south exposure, if possible, so as to secure the warmth and light of direct sunshine.

The main part of the barn is 36 by 70 feet and is divided into eleven, 10 by 14 feet, feeding pens; it also provides a store room, containing the stairway for the loft and a mixing room, each of the same size as the pens. The other part of the barn is 30 by 40 feet and contains six pens, a horse stall and a man's room each 10 by 11 feet in size. The building is designed with 18 foot posts, the lower story being 7 feet high, thus providing a large hay loft above. Hopper shaped bins, as shown in some of the other plans in the bulletin, may be provided in the loft above the mixing room whence the ground feed may be spouted into the mixing troughs. This plan may readily be made larger or smaller as desired without effecting the outside appearance or altering the general scheme of arrangement.

The partitions between the pens are made readily movable so that they may be taken out when desired. The feeding racks are made of light wooden slat work hinged to the pen partitions and supported at the proper angle by means of chains. They fold up compactly against the partitions when the latter are being moved or stored away when not wanted.

The silo is conveniently located and opens into the feed room from whence the silage and feed may be distributed with the same carrier and without any extra track.

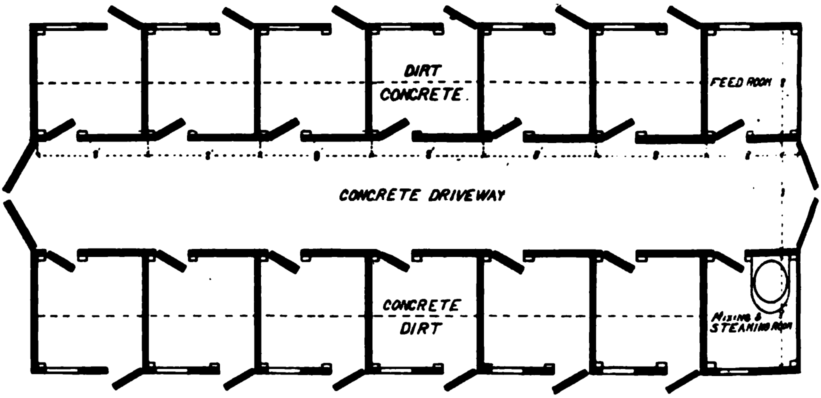
Although the plans show a concrete silo, it may be built of either brick or wood if desired. The silo is 14 feet inside diameter and 20 feet inside height and has a capacity of from 40 to 45 tons of silage.

HOG HOUSES

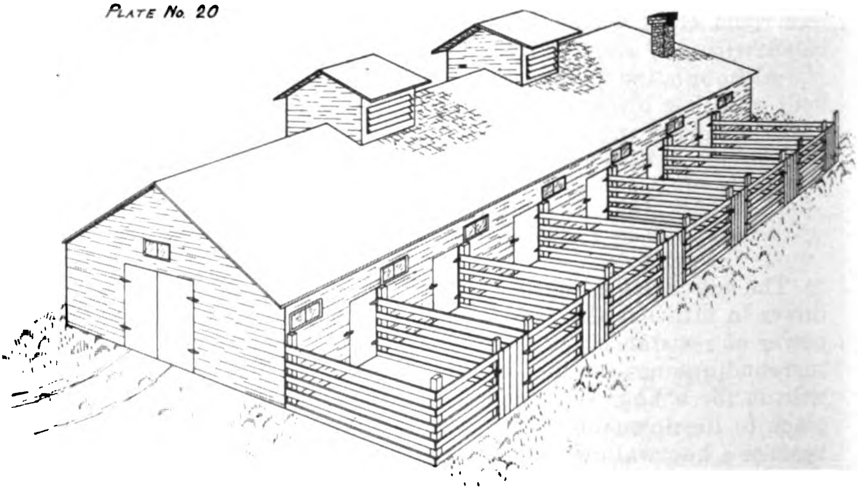
Plate No. 20.

The hog is not by nature an unclean animal and does not thrive in filth but the fact that he is endowed with a great power of resistance and the ability to make the most of his surroundings has created the popular notion that anything will do for a hog. The hog will invariably choose a clean place to lie down on if the opportunity is given him and because a hog wallows in mud does not indicate that he prefers filth but that, owing to the fact that he perspires but little, he requires moisture to cool him during warm weather. A concrete hog wallow should, therefore, be provided in the hog lot for this purpose. Hogs in order to give the best returns should have clean, warm, well-lighted and ventilated quarters free from draft and dampness.

A hog house built along the lines indicated by plate 20 will be found excellent for North Dakota conditions. The plans show a house 56 by 24 feet containing twelve 8 by 8 pens with removable partitions so that the pens may be



FLOOR PLAN AND PERSPECTIVE of HOG HOUSE

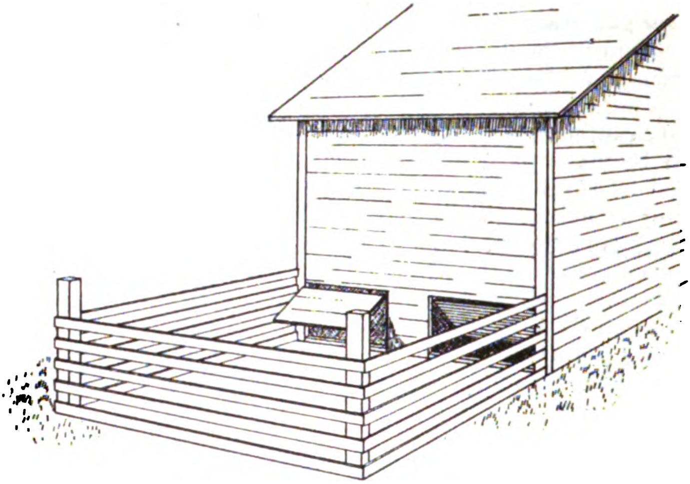


readily enlarged when desired. Fenced pens are arranged outside as shown in the perspective and communicate with the inside pens by doors through the side walls of the building. Instead of the doors shown in the perspective, self-closing pen doors of the type illustrated in the upper drawing of plate No. 21 may be substituted. These doors have the advantage of being always closed thus excluding dampness, cold and drafts from the building. The doors must be made to swing both ways and this can be accomplished by suspending them from the upper part of the door casing by means of bolt hooks and by bolts or suitable hinges, this permits the hogs to go in and out as they please—the doors closing after them. These doors must be fastened up when the pen is occupied by a sow with a litter of pigs. If it is desired to have the doors fit closely leather strips, forming a flexible but tight joint with the door when closed may be nailed around the casing. Some hog raisers prefer extra slide doors which may be closed during cold weather.

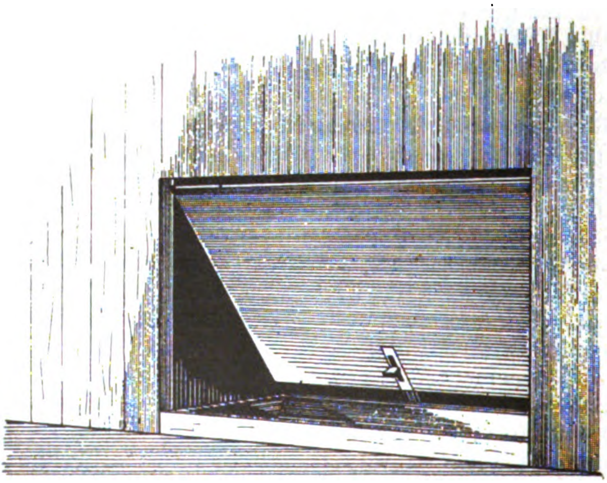
Another convenience for hog houses is the swinging door shown in the lower drawing of plate 21. This door is intended to be used in connection with the feed trough to facilitate feeding. The door is suspended by hooks and staples or two pins, one in each side of the frame. When feeding the hogs the door is swung back, as shown, and is held in place by shoving the bolt below the edge of the trough. This arrangement gives easy access to the trough for cleaning it or pouring in the feed and at the same time excludes the hogs.

The cost of the building may be somewhat lowered by dispensing with the 8 foot driveway and substituting a 4 foot feeding alley thus reducing the width of the building four feet. It will be found, however, that the added convenience and the greater volume of air provided by the driveway make it desirable. As indicated, the floor of the driveway and inner half of the pens is made of concrete while the outer half of the floor is dirt. This is arranged so that the hogs may sleep in the back part of the pens, where the floor is not cemented, to comply with the objection of some hog raisers that concrete sleeping floors make the hogs subject to rheumatism. This arrangement is not entirely satisfactory and a better way is to make the entire floor concrete and place a removable wooden floor on top of the concrete in the sleeping quarters. This wooden floor should be laid on cleats so as to permit an air space between it and the concrete and the boards should be laid with quarter

PLATE No. 21



SELF-CLOSING PEN DOORS



SWINGING DOOR FOR HOG HOUSE

inch spaces so as facilitate drainage. A drainage gutter with a sufficient slope may be provided in the concrete underneath the board floor and along the side wall. The concrete should be laid with a gentle slope towards the gutter. These wooden floors are desirable but concrete is not objectionable where an abundance of litter is provided.

This plan may be readily altered to suit the requirements of hog raisers who prefer to have both sleeping and feeding pens inside the building, by eliminating the driveway and placing two rows of pens togther so that opposite pens communicate with one another by means of a door or opening. A four foot feeding alley must then be provided along one side wall. The feeding pens should be separated from one another by means of gates wide enough to drive through so that when the house is to be cleaned the hogs may be temporarily shut up in the sleeping pens and a manure spreader hauled through the feeding pens which will contain nearly all the manure. This makes a convenient and up-to-date arrangement but is more expensive of room than the plan shown which in the estimation of the writer is to be preferred as the manure will then be largely outside of the building, making its interior cleaner and more sanitary.

At the farther end of the building is located an 8 by 8 feed room on one side of the driveway and opposite it a mixing and steaming room of the same dimensions. This room will also serve as a slaughtering room and a large bricked-in iron kettle should be provided for cooking the feed and scalding the slaughtered swine.

The building will accomodate fifty hogs without being crowded and if properly constructed of suitable material will be well lighted and ventilated and possess sufficient warmth even at farrowing time which is the most critical period in the business of hog raising.

A LAYING HOUSE FOR HENS *

Plate No. 22.

The winter housing of laying hens has always been a live problem among the poultry keepers of North Dakota owing to the somewhat severe climatic conditions. For some years the poultry department of the state Experiment Station has been investigating types of houses best adapted for winter layers. The writer has gathered ideas on poultry house construction from personal visits to poultry plants

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*From Press Bulletin No. 36 by Prof. O. W. Dynes.

in the large centers of the industry and, with a practical experience in raising poultry in North Dakota, planned the following poultry house which has been constructed on the station grounds and has been eminently satisfactory.

SIZE.—The dimensions of the house are 14 by 36 feet shed roof style, 8 feet 6 inches high in front and 5 feet high behind. It is divided into two equal sections, 14 by 18 feet in size. Each pen is sufficiently large for 100 hens.

FOUNDATION WALLS AND FLOOR.—The walls are built of cement 8 inches wide by 20 iches high and are sunk into the ground 9 inches. The proportion is 1 part Portland cement, 2 1-2 parts clean sharp sand and 5 1-2 parts gravel. The floor space between the walls was filled in with cinders. Dirt will do equally well for this purpose. The cement floor was then laid using a proportion of 1 of Portland cement to 2 of sand for the wearing surface.

There are other kinds of floors that may be used. Cement is most expensive but has greater permanency. Ordinary board flooring would be the second choice in a house of this kind.

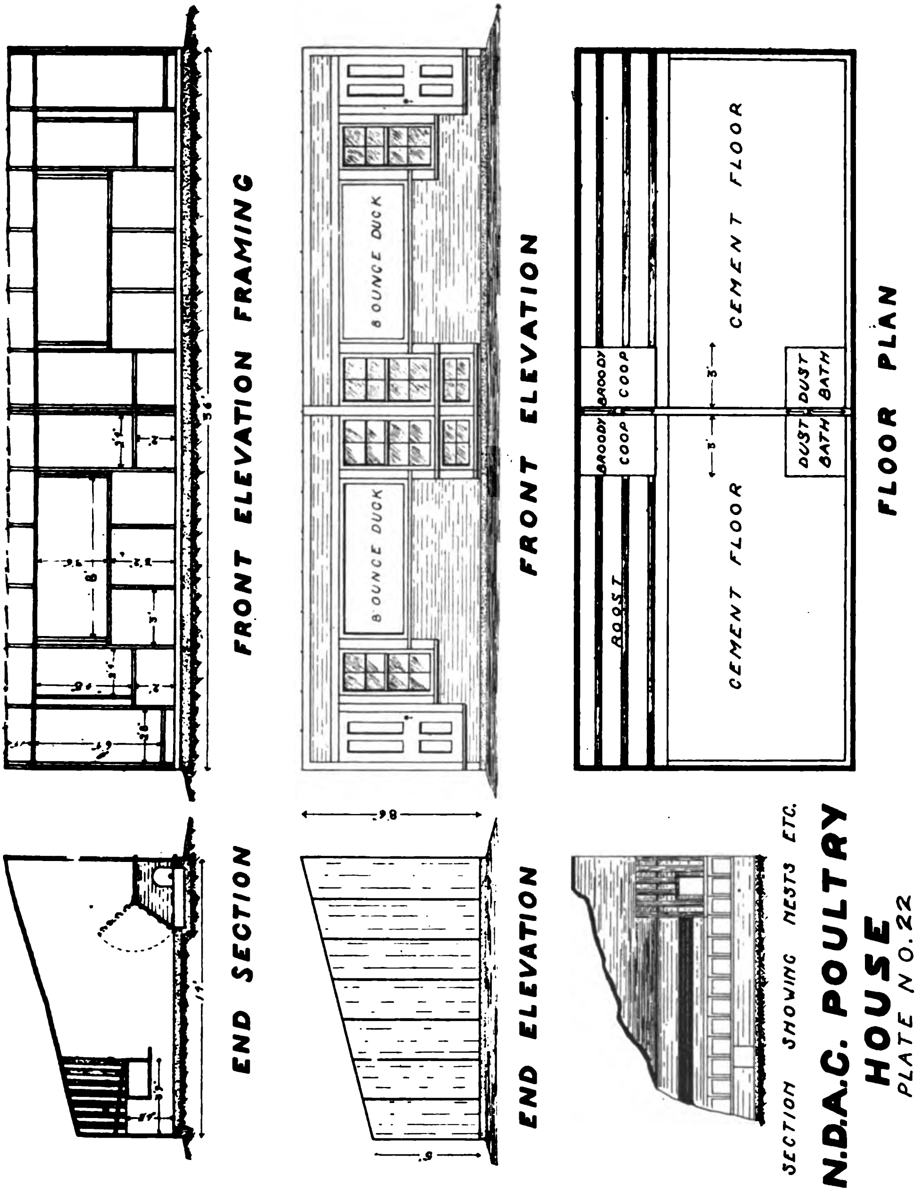
FRAMING.—The entire house is single boarded with the exception of the back wall and that part of the roof above the roosts, which is double. No. 2 matched and grooved 6 inch flooring is used. A good durable roofing paper is used on the outside walls and roof with the exception of the front wall.

The sills and rafters are made of 2 by 6 inch pieces two feet apart. The studding are the same distance apart, but are made up of 2 by 4 pieces. All of the windows and door openings are in the front wall with the exception of two small doors in the rear for the passage of the birds to the yards.

GLASS WINDOWS.—Two large four pane windows 2 feet 4 inches by 4 feet 8 inches are placed in each section. Each pen also contains one small four pane window 2 feet by 2 feet 4 inches which is placed near the floor, directly under one of the large windows. This throws light on the dust bath.

CURTAIN WINDOWS.—A large opening 8 feet by 3 feet 6 inches is placed between the two large windows and is covered with a heavy muslin or eight ounce duck frame which is hung on hinges and opens outwards.

WINDOW FRAMES.—All window openings are covered on the inside with removable wire frames made of inch mesh poultry netting.



N.D.A.C. POULTRY HOUSE
PLATE NO. 22

DUST BATH.—Countersunk in the cement floor of each house section on the inside corner directly under the window is a depression 3 by 3 feet in size and six inches deep. A flat topped board covering is placed over the dust bath at the height of the small window, with sides extending to the floor. This prevents the dust from escaping into the main body of the house. A small opening is left on the side for the passage of the birds into the dust bath. This flat top makes a splendid place for the drinking fountain, as it is well out of range of the dust and straw from the busy feet of the hens. A slatted runway allows the birds access to the water.

ROOSTS.—The roosts extend the whole length of the back wall in each section, except three feet next the partition wall which is reserved for the broody coop. The dropping board is 3 feet 9 inches wide and is made of matched flooring put together with screws. Pieces 2 by 3 inches in size make up the roosts proper and three of these strips are placed on iron rests 12 inches apart and 8 inches from the dropping board.

BROODY HEN COOP.—This coop is made of two inch strips extending to the roof in a vertical manner and rests on a standard built up four feet from the floor. A hinged door 14 by 20 inches in size opens outward in front.

VENTILATION.—Ventilation is provided for by leaving two openings 8 by 12 inches in each section close to the ground in the outside wall. An ordinary grate register opens or closes the openings at the will of the operator. The air flue thus consists of two of the studding and the inner and outer wall. The air passes up and comes up into the body of the house in front of the roosts. The cloth curtain on the window openings allows the air to pass through. acting as a sieve, but prevents any draughts.

CURTAINS.—Curtains made of eight ounce ducking are stretched on light wooden frames and cover the large window openings. A heavy muslin curtain can also be used for this purpose. Stretched acress the whole length of each house section and attached above and in front of the roosts is a roll curtain made of heavy muslin. This is raised and lowered by means of light ropes in stage curtain fashion. It is dropped during the cold nights of winter after the fowls have gone to roost.

PARTITION.—The partition between the sections is made of inch mesh chicken wire and a swing door with reversible hinges allows passage from one part of the house to another.

NESTS.—When trap nests are not used, almost any type of a box nest will suit. The nests should be easily removed and may be placed under the dropping board or at the ends of the house.

A poultry house of this description can be made very attractive if painted and it should be repainted at least every other year. The roofing paper as well as the front wall should receive a coat of paint as the paper will last longer under such treatment. The house should be built facing south and on slightly rising ground, thus ensuring good drainage.

BILL OF MATERIALS

LUMBER—	
2200 ft. No. 2 D & M at $30. per M	$66.00
62 pieces 2x4 in.—14 ft.—579 ft. at $25.00 per M.	14.47
30 pieces 2x6 in.—16 ft.—480 ft. at $25.00 per M.	12.00
12 pieces 2x4 in.—18 ft.—144 ft. at $27.00 per M.	3.88
5 10-ft. strips quarter round	.60
10 squares of Two ply Durabul roofing at $2.10 per square	22.10
2 house doors 2 ft. 8 in.x 6 ft. 6 in. at $2.70	5.40
4 large windows 2 ft. 4 in. x 4 ft. 8 in. at $1.90	7.60
2 small windows 2 ft. x 2 ft. 4 in. at $.80	1.60
HARDWARE—	
4 grate registers at $ .80	3.20
1 pair reversible hinges	1.50
2 pair large door hinges at 20 cts.	.40
3 dozen small hinges at 20 cts.	.60
2 mortise door locks at $ .50	1.00
20 sq. yds. wire netting $1.00, 75 lbs. 8d nails, 20 lbs. 10d at $4.75	5.75
6 frames $12.00, Ducking, curtains and rollers $7.81	19.81
Total	$165.91
Cement Floor Construction	90.00
	$255.91

DETAILS OF CONSTRUCTION

FRAMING.—An examination of farm barns throughout the state has convinced the writer that a large number of these structures are erected without due regard to the securing of sufficient strength. In many instances the trouble may be traced to the roof which has been ineffectively braced to withstand the heavy load it must sustain when hay is unloaded with forks or slings; the result being that the roof sages with a consequent bending of plates and bulging of walls. Weakness in this respect has been noticed especially in curb roofs which have become very popular for barns because of the large room they afford for the storage of hay. Curb roofs subject the side walls to less lateral strain than any other pitched roof but on account of the comparatively flat pitch often given the upper part of the roof and the tremendous windload a high roof of this type must sustain together with the extra weight when unloading hay it is necessary that this kind of a roof be thoroughly braced. If roofs of this construction are properly braced as shown in some of the plates in this bulletin, each side forms a truss which, meeting at the ridge cannot sag or yield. The result is that it becomes one of the strongest and best types of barn roof construction with all braces out of the way so that no valuable space is lost.

The proper shape and construction of a barn roof depends in a great measure upon the size and height of the barn, the external effect and the amount of hay it is desired to store. The pitch of the roof should be governed by the appearance, the climate and the strength required. High pitched roofs are best adapted to North Dakota conditions as they shed rain better and the winds get less purchase on the shingles. The lowest permissable pitch for a shingled roof is a rise of four inches to the foot which is very flat and should be tolerated only in cheap shed constructions. A pitch giving from eight to twelve inches rise in a foot will be found best suited for barn roofs.

During the early days in localities where timber was plentiful barn frames were commonly constructed from a few heavy timbers made rigid by the use of correspondingly heavy braces. This type of construction has not been found practical in a section where the absence of timber requires the importation of all lumber for building material. The so called balloon frame requiring two inch material is cheaper and more practical. It derives its rigidity principally from the strength of the sheeting or siding which can not be taken advantage of in the old style construction on account of the distance apart of the frame timbers.

The balloon type of construction has led many builders to depend too much on the stiffness of the wall and roof boards with the result that large barns are often built that are too weak to withstand the heavy windloads when empty and the weight and lateral pressure of hay when filled. A considerable saving in size of timbers can often be accomplished by the proper use of braces and they should be employed wherever they will effect a saving of material or add necessary strength. As an illustration of the importance of bracing may be cited that to shorten the free span of a 16 foot joist two feet at each end by bracing enables it to carry a 25 per cent greater load on the resulting 12 foot span besides the load which it will carry on the short two foot spans at either end.

The present high price of lumber makes it a question of considerable economy to so proportion the floor joists and other timbers that they have ample capacity to carry the maximum loads placed on them without the unnecessary waste of material. This necessitates a consideration of the strength of materials, complete formulas and tables of which can be found in any good builders handbook. White pine is by far the most common material for barn frame construction. The following formula for determining the safe load evenly distributed, for white pine will be found convenient for calculating the size of beams and joists:

$$\text{Safe load} = \frac{\underset{\text{(in inches)}}{\text{Breadth}} \times \underset{\text{(in inches)}}{\text{Square of depth}} \times 150}{\text{Span in feet.}}$$

To illustrate the use of the terms employed—the breadth of a 2 by 8 set on edge is 2 and its depth is 8. If the timber is laid flat the breadth becomes 8 and the depth 2. The breadth and depth are to be used in inches and the span in feet. By span is meant the distance between the inner edges of the supports. The square of the depth means the depth multiplied by itself.

To show the working of the formula—find the safe load, evenly distributed, of a white pine joist 2 by 10 with a 12 foot span.

$$\text{Safe load} = \frac{2\text{x}10\text{x}10\text{x}150}{12} = 2500 \text{ lbs.}$$

If the safe center load is desired divide the result of the formula by two.

To find the safe load on a floor, or section of a floor, that is a free span multiply the safe load of one joist by the number of joists in the floor. The sills are not to be included and neither is the flooring as it would support little but its own weight if the joists were removed.

In this formula the safe load is taken as one sixth of the theoretical breaking load. This is a sufficiently large margin for hay mow floors which should carry this load with but slight deflection even though some inferior timbers are used in the construction.

FOUNDATIONS often fail or settle unevenly not so much because they are too light as because they are poorly proportioned. A foundation should be so constructed that its size at any point is proportional to the weight to be carried at that point. If it is designed on this plan it cannot settle unevenly if the soil on which it rests is uniform. A very common mistake is to make the foundation under the outside walls unnecessarily heavy while that under partitions, often carrying several times the load, are entirely too light with the inevitable result that the building settles unevenly. The width of a foundation must be such as not to exceed the safe bearing power of the soil. The bearing power of the soil on the Station grounds is estimated at from 2 1-2 to 3 tons to the square foot but barns, unless they contain exceptionally large hay lofts, will not exceed this weight on a foundation of ordinary width.

At present prices concrete makes the best barn foundations where good sharp sand and gravel can be obtained cheaply. Concrete possesses the advantage over brick or stone that it fits the sills perfectly and also conforms to the bottom of the trench instead of leaving cavities and openings as is sometimes the case with stone; it has considerable transverse strength and if there is a wet or soft spot under the foundation it is rigid enough to span it if the length is not too great. A satisfactory proportion for foundations is 1 part Portland cement 2½ parts sand and 5½ parts crushed rock or gravel.

FLOORS.—The problem of providing a suitable floor for barns that is low in first cost, yet durable and sanitary is an imporant one. Cement concrete, although somewhat higher in first cost than wood, meets the requirements of a good floor better than any other available material and the writer does not hesitate to recommend concrete floors for all types of barns. Concrete floors are considered best for several reasons. 1. They are economical because they are durable. Wooden floors last from three to five years with a maximum of about ten years, if of the best construction, while the durability of good concrete floors equals that of the building. 2. They save labor because of their evenness which permits of thorough and easy cleaning. 3.

They are sanitary not only because they can be kept clean, but because they are easily drained and are water tight enough to exclude ground water and prevent the liquid manure from leaching into and polluting the soil.

The chief objections to concrete floors are that they are cold and slippery. To the first may be replied that in reality concrete is no colder than wood subjected to the same temperature but on account of being a better conductor of heat concrete carries away the bodily heat of the animals faster if they come in direct contact with it. This is not a serious objection for even wood is too cold for animals to lie on without bedding which should be supplied liberally on any floor. Straw is a poor conductor of heat and if a sufficient amount of bedding is used the bodily heat of the animals will be retained as well on concrete as on wood which is apt to be more or less wet and soggy. A generous use of bedding is desirable not only because it adds to the comfort of the animals but because of the increased amount of manure which in turn means increased fertility of the farm. The objection of slipperiness may be overcome by making the wearing surface scored or grooved into blocks before it has hardened. These sections made from 4 to 6 inches square furnish a good foot hold for the animals and make a very neat appearance.

The floor should be raised about one foot above the surface of the ground to insure drainage. If earth has been filled in to secure this elevation it must be thoroughly compacted so as to prevent uneven settling and subsequent cracking of the floor. It is a good practice to make the desired fill as soon as the foundation is completed because it can be done more conveniently at that time and the fill will have proper time to settle before the floor is put on.

Concrete stable floors should be about 5 inches thick. The lower 4 inches should be made of concrete in the proportion of 1 part cement, 2½ parts clean, coarse sand and 5 parts screened gravel or broken stone and finished, before the concrete has set, with a 1 inch mortar of 1 part Portland cement to 2 parts clean and coarse, but sharp sand. If the sand or cement are not first class this proportion had best be changed for horse barns at least to 1 part cement to 1½ parts sand.

Before laying the concrete a foundation of porous material such as cinders or gravel, should be spread evenly on the surface and thoroughly tamped down. The depth of this foundation will depend upon the drainage of the soil but where a fill of one foot of earth has been provided, as previously described, this foundation need not be more than four inches thick.

THE MANGERS used in up-to-date barns vary considerably in shape and size, dependent upon the ideas of the owners, but whatever the difference in design the consensus of opinion seems to be that concrete is the best material for this construction. The design shown in the upper figure of Plate 23 is simple to construct and meets every requirement. As shown in the figure it is 20 inches wide and 6 inches deep. The retaining wall between the manger and stalls, while high enough to prevent the waste of hay, is not so high as to catch the breath of the cow. The bottom of the manger is on a level with the cow's feet which is the natural height at which she procures her food when grazing. The width is sufficient to prevent cows from throwing hay out of reach and the feed alley floor is on a level with the top of the manger and sloping towards it, which makes feeding very convenient and the alley easy to clean. The bottom is so shaped that a minimum amount of water is required to permit cows to drink out of the manger.

The manger should be made at the same time as the floor and with concrete and facing of the same proportions. The construction is very simple. A plank set on edge on the stall side and two templets—one for the concrete and the other for the facing is all that is necessary. The templets are made from boards cut in the desired shape, the one for the concrete being made larger so as to allow for the 1 inch facing. The bottom should be given a slope of 3 inches in 50 feet so that water may be readily drained out of the manger at the lower end.

MANURE GUTTERS, like mangers, differ in size and shape but for concrete floors the design shown in plate 23 is most common. This gutter is 6 inches deep and 14 inches wide. Some cattle men prefer gutters 16 to 18 inches wide and only 4 inches deep, still others place the stall as much as 12 inches and the manure alley 6 inches above the gutter bottom. In order to facilitate the draining away of the liquids a three inch U-shaped channel is sometimes made in the bottom of the gutter next to the manure alley but this is not necessary where a slope is given the gutter bottom. The gutter should be given a uniform fall of 3 inches to 100 feet and the floor of the manure alley should have a slope towards the gutter of 1 inch in 10 feet. The stall floors should be given a 1-inch drop from manger to gutter.

A small water tight liquid manure cistern may be provided outside the barn into which the gutter drains but if a manure shed is used the cistern should be in the shed. The gutter should be connected to the cistern by means of a drain pipe effectively trapped like the soil pipe in a house and so arranged that the trap may be easily cleaned.

STALLS, although the question of economy and first cost must not be lost sight of, should first be considered from the standpoint of the humanitarian and no patented or home-made stall should be decided upon unless it is made so as to insure the greatest possible comfort for the animals. This is no mere sentiment but sound business and any reasonable expenditure in this direction is money well invested. This is true for all types of cattle but more especially so for the dairy cow which is a very sensitive creature highly susceptible to kind treatment. If she is kept clean and comfortable all her energy will be devoted to the production of milk while, if her quarters are filthy and uncomfortable a certain portion will be diverted and lost. This has been conclusively proven time and again by the almost fabulous yields of milk or butter fat from cows when given ideal care and treatment.

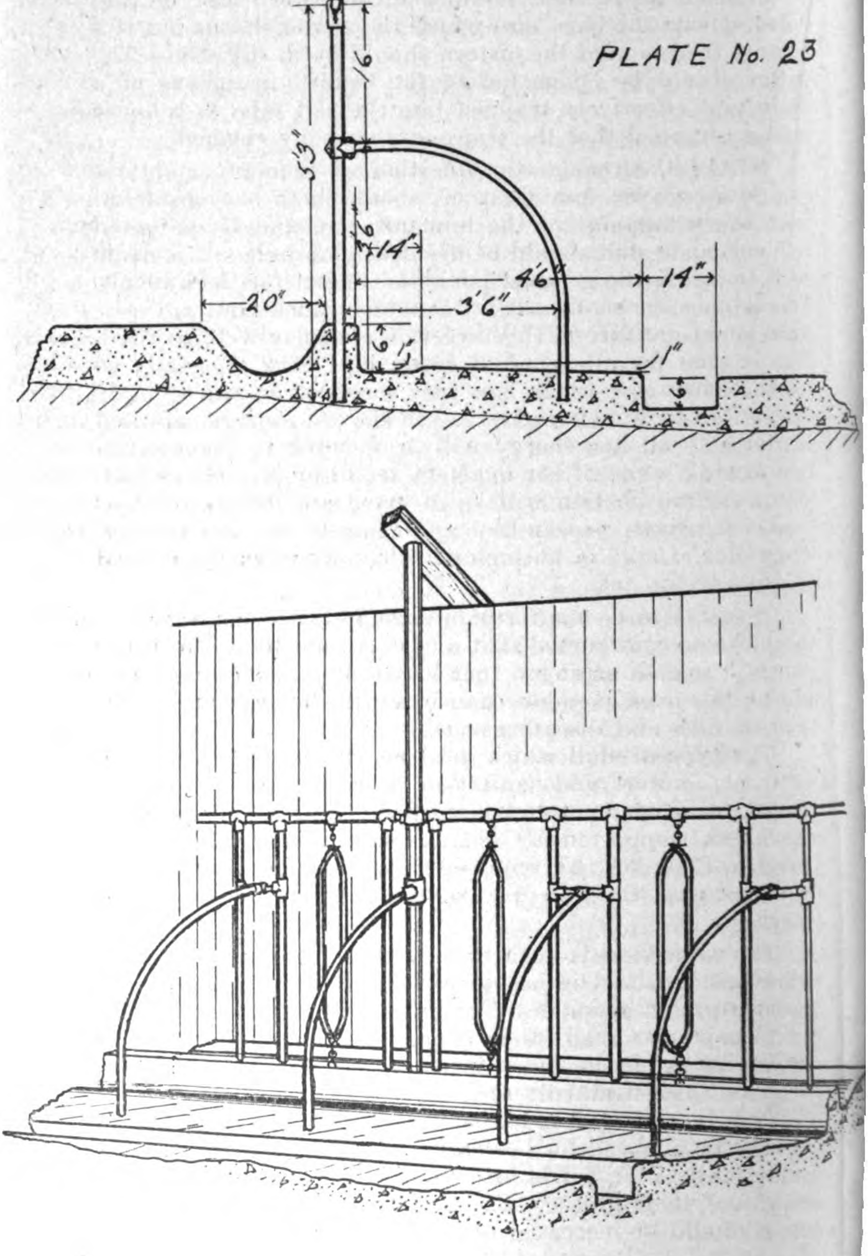
A stable to be comfortable must needs be sanitary. It should be so constructed that a cow can not lie down in her own filth and so arranged that it can be easily cleaned and affords the least possible chance for the permanent lodgement of filth and disease germs.

The type of stall which most nearly meets the requirements of comfort and sanitation is undoubtedly some approved form of the tubular steel stalls with tubular steel stanchions, supported by chains, and concrete floor as shown in Plate 23. All required dimensions are given in the drawings with the exception of the stall which is 3 feet 6 inches.

The stanchion is so arranged that its lower end may swing nearly a foot in any direction while the upper end is almost equally movable. This wide latitude permits the cow to move her head freely from side to side, allows her to rest, stand up, or lie down in a natural position almost as easily and unrestrainedly as if she were untied.

This type of stall is intended especially for dairy cattle but may be adapted for beef cattle as well. For beef cattle double stalls 7 or 8 feet wide are considered best and on account of their greater size, the distance from manger to gutter should be increased to 5 feet.

PLATE No. 23



There are many well known types of wooden stalls that meet the requirements of a good stall fairly well. They are cheaper in first cost than the stall described and can easily be constructed by a carpenter or the farmer himself. It would be beyond the purpose of this bulletin to give details of these several stalls but drawings and descriptions can be easily secured elsewhere.

WINDOWS.—Sunlight is Nature's greatest germicide —it makes for health and efficiency among animals as well as people and yet the semi-darkness of a medieval dungeon prevails in a great many barns. There is no good reason for this deficiency except that it is customary, for—windows of sufficient size do not add greatly to the cost of a barn and, if properly put in do not materially reduce the temperature in winter. Four square feet of window surface for each animal is the least that should be provided and for dairy barns 6 or even 8 square feet will be found beneficial. Windows that are long up and down admit much more light than windows of the same dimensions with their long axes horizontal. Windows near the ceiling admit more light and distribute it better than windows placed low on the wall. Then too, they are less likely to be broken. A south exposure is desirable, especially for swine and poultry. South windows admit direct sunshine in winter when the sun is low, but on account of the height of the sun, are not as hot in summer as is generally supposed.

VENTILATION of barns is usually even more deficient than window space and to this lack of proper ventilation veterinarians attribute, in a large measure, the prevalence of tuberculosis and other zymotic diseases . As is well known tuberculosis may be transmitted to people through milk or meat from infected cattle and it, therefore, becomes of the greatest importance to secure adequate ventilation for all cattle barns. But, aside from safe-guarding the health of both the owner's family and his cattle good ventilation is economy. Perfect assimilation of food is no more possible in the body of an animal without a sufficient supply of air than is perfect combustion of fuel in a furnace with the draft closed. In order that milch cows or beef animals may respond to an increased ration of feed more air must be supplied for its combustion as surely as that a furnace requires more air for a heavy than a light fire. In other words—the amount of milk or beef produced by the animal and the amount of heat produced in the furnace depend as much on the air supply as on the amount of food and fuel. If a barn is poorly ventilated it is futile, therefore, to expect the largest returns in beef or milk for the feed consumed.

With our cold winters deficiency in ventilation is no doubt, in some measure, due to the prevailing notion that thorough ventilation is incompatible with sufficient warmth. This is a serious mistake for, unless the weather is very severe, a barn properly constructed is more apt to be too warm than too cold. A barn is warm enough for cattle fed for milk or beef production if its temperature never falls below forty degrees and where the temperature may be ordinarily maintained at about fifty degrees. Data secured from observance of the temperature in barns thoroughly ventilated conclusively proves that proper heat and ventilation may be enjoyed simultaneously.

The trouble with the average barn, then, is evidently improper construction. Most barns are built with a single board wall and without window casings. The result is that the heat passes out through the walls but leaves the foul air and dampness within. In this way heat is lost without securing adequate ventilation in return. If a barn is to be properly ventilated the walls must be made as tight and as good non-conductors of heat as possible. The wall should be double with drop siding on the outside and building paper and matched flooring or sheeting on the inside. This makes a sufficiently tight construction and the dead air space will minimize the loss of heat through the walls. If hay is stored in overhead mows the ceiling need not be double boarded as the heat will be effectively retained by the hay. When barns are built in this way ventilation can be readily effected and the building yet retain sufficient heat for the comfort and well being of the animals.

Many schemes have been promulgated for the ventilation of barns and other buildings but none have been more successful than the King system when properly installed. This system has proved its worth by effective action in a large number of buildings and under a variety of climatic conditions; the failures which have been reported being due to improper installation or too open walls which destroy its action.

The essentials for the success of this system may be crystallized in the following statements:

1. The walls should be double boarded and walls and ceiling must be as nearly air tight and as good non-conductors of heat as is consistent with economy.

KING SYSTEM OF VENTILATION

PLATE No 24

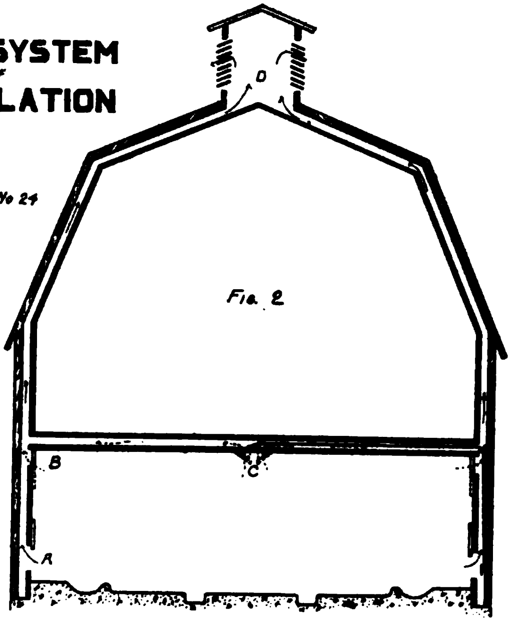
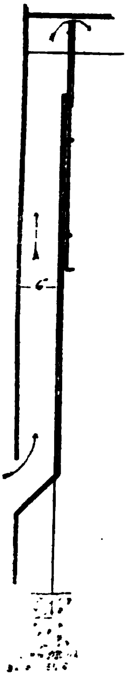


FIG. 2

FIG 1



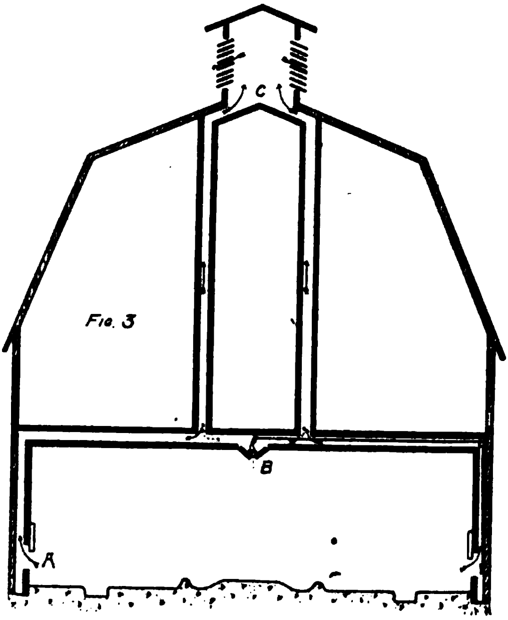


FIG. 3

2. The air should be made to enter and leave only through appropriately designed and arranged flues. If this is done the heat lost will be utilized in ventilating the building.

3. The foul air flues should be of air tight construction with walls protected so as not to destroy the draft by allowing the air to cool too rapidly. They should be at least twenty five feet in height with inlets about one foot from the floor. They shoud be as straight as possible and with a capacity sufficient to insure rapid enough change of air.

4. The fresh air flues must be air tight and should have their inlets near the foundation of the building and their outlets within eight inches of the ceiling. They should not be more than 12 feet apart to insure proper air distribution and should have a joint capacity slightly exceeding those of the foul air flues.

The King system of ventilation adapted to barns is shown in the figures of plate 24. Figure 1 shows the construction of an intake flue. These flues should be as nearly air tight as possible and are best constructed from galvanized iron but a flue made by lining the space between two wall timbers with building paper will answer very well The air enters the flue near the foundation, or at least three feet lower than the outlet, and is delivered hrough an opening near the ceiling. This opening is controlled by a shutter which may be conveniently arranged as shown. The air is admitted near the ceiling so that it may mingle with the warm air before reaching the animals. As previously stated these flues should not be more than 12 feet apart so as to insure good distribution of the fresh air.

Figures 2 and 3 show two different arrangements of the foul air flues but they may be arranged in a variety of ways to suit any particular building. It must not be lost sight of that, like a chimney, their efficiency depends upon their drafts and it is, therefore, absolutely essential that their walls be, not only air tight, but, sufficiently good nonconductors of heat so that they do not cool the air too rapidly. Galvanized iron is probably the best material for their construction as it is not only air tight but its smoothness minimizes friction. The iron should be covered with a casing of boards and building paper so as to make the flue walls retentive of heat. Matched boards lined with building paper may be used with good results, in lieu of galvanized iron, as it is cheaper. The flues should be made as straight as possible for bends or turns materially restrict the draft. It should also be remembered that a flue has no greater capacity than its smallest area so that wherever it must be built around a beam, for example, its area at that point should be proportionately increased.

Contrary to the popular notion that foul air accumulates near the ceiling, the intake of the foul air flues should be within a foot of the floor as shown at AA in the figures. Warm air ascends because it is lighter than cooler air but the carbon dioxide and the various organic poisons exhaled from the lungs are heavier than air and remain near the floor. In figure 2 the flues are built along the outside walls and under the roof, terminating in a ventilator. The registers B and C are for the purpose of rapidly cooling the barn and are to be left tightly closed except when the barn is too warm. The horizontal flue under the ceiling will help keep the barn cooler in summer but is not essential and may well be omitted. Figure 3 shows two flues extending up through the hay mow but far enough apart so as not to interfere with the hay fork. This is considered a better arrangement because the flues passing up through the hay will not be cooled as much as when along the outside walls and a better draft will result. Where there are partitions in the stable the flues should pass down these partitions thus eliminating the cooling effect of the outside wall and at the same time securing a straight flue.

Foul air flues should not, if possible, be less than 25 feet in height but, if lower their area must be increased. Their capacity must be sufficient to insure the change of air required by the animals housed. The following table* based upon experiments and calculations made by Professor King shows the number of cubic feet of air per minute required for different domestic animals:

For horses	71.	cu. feet per minute per head
For cows	59.	cu. feet per minute per head
For swine	23.2	cu. feet per minute per head
For sheep	15.3	cu. feet per minute per head
For hens	0.524	cu. feet per minute per head

From deductions and experiments made at different temperatures with foul air flues 25 to 30 feet in height Professor King assumes the average velocity of air through a properly constructed foul air flue to be 295 feet per minute. With this data the size of flues for a barn accomodating any number of animals may be readily computed .

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*From Wisconsin bulletin No. 164.

If, for example, it were desired to compute the area of flues for a barn for 20 cows:

$$\text{The area} = \frac{59\text{x}20}{295} = 4 \text{ sq. feet}$$

This area may be divided into two flues of 2 equare feet each or four flues of 1 square foot each.

When a barn does not contain the number of animals for which it is designed the intakes may be partially closed so as to restrict the ventilation an amount proportionate to the number of cattle in the barn. This may become necessary in a partially filled barn to keep it from getting too cold.

SILOS.—Before building a silo the required capacity should be carefully determined. Its capacity will depend upon the size of the herd, the amount of silage to be fed each animal daily, and the number of days silage is to be fed. One cubic foot of settled silage weighs about 40 lbs. and when fed in conjuction with other feeds constitutes an average daily ration for one animal. On account of the long winters in North Dakota silage must be fed about 200 days in the year and consequently one cow will require 8000 lbs. or 4 tons of silage. From this consideration the capacity of a silo for any number of animals may be readily calculated.

Another important consideration that must not be overlooked in the construction of a silo is that its diameter should depend upon the amount of silage fed per day. Professor King has found that after feeding of silage has commenced it has a tendency to mould and spoil if fed down at a less rate than 1.2 inches daily. The diameter of a silo should, therefore, be such that the surface is lowered as rapidly as is required to keep the silage fresh.

The following table, adapted from a table in King's Physics of Agriculture, gives the inside diameter of silos for different sized herds when the feeding surface is to be lowered at the different rates indicated:

Feed for 200 days

No. of Cows	Tons	Silo 20 ft. deep Rate 1.2 in. daily Inside Diameter		Silo 25 ft. deep Rate 1.5 in. daily Inside Diameter		Silo 26.6 ft. deep Rate 1.6 in. daily Inside Diameter		Silo 33.3 ft. deep Rate 2 in. daily Inside Diameter	
		ft.	in.	ft.	in.	ft.	in.	ft.	in.
10	40	11	11	10	2	10	4	8	9
15	60	14	7	12	5	12	8	10	9
20	80	16	10	14	4	14	7	12	5
25	100	18	10	16	0	16	4	13	10
30	120	20	8	17	6	17	10	15	2
35	140	22	4	18	11	19	4	16	4
40	160	23	10	20	3	20	8	17	6
45	180	25	7	21	5	21	11	18	7
50	200	26	8	22	7	23	1	19	7

The heights given for silos in the table are for settled silage and in order that the silo may contain it at the time of filling about 5 feet should be added to the height in each case. This depth may be below ground where drainage is good and it is desired to keep the height above ground at a minimum.

No attempt will be made to discuss the construction of silos in this bulletin as a large number of good bulletins have been prepared on the subject by the different experiment stations and the U. S. Department of Agriculture.

* Information regarding silos and silage is contained in the following Farmers' Bulletins of the U. S. Department of Agriculture: No. 32. "Silos and Silage;" No. 292, "Cost of Filling Silos;" No. 56, pp. 7—9, "Robertson Silage Mixture;" No. 103, pp. 20, 21, "Silage for Horses and Hogs," and pp. 23—30, "The Stave Silo;" No. 124, p. 25, "Alfalfa Silage;" No. 133, pp. 31, "Losses in the Preparation of Silage;" No. 190, pp. 21—23 , "The Octagonal Silo;" No. 222, pp. 31, 32, "Silage in Place of Grain for Dairy Cows;" No. 267, pp. 29—31, "Effect of Silage on the Flavor of Milk;" No. 309, p. 19, "Silage from Frosted Corn."

*Any of these publications can be obtained by writing to the U. S. Department of Agriculture, Washington, D. C.

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NORTH DAKOTA
AGRICULTURAL COLLEGE

GOVERNMENT AGRICULTURAL
EXPERIMENT STATION
OF
NORTH DAKOTA

BULLETIN NO. 98

THE SILO AND IT'S CONSTRUCTION

BY

J. H. SHEPPERD
G. L. MARTIN
R. M. DOLVE

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The Silo and it's Construction

The silo is used to preserve in a succulent form all kinds of green fodder crops including oats, barley, wheat, rye, millet, peas, clover, alfalfa and corn. The corn plant makes the best silage and is the most widely used. About 37% of the food value of the entire corn plant is in the stalks, leaves and husks. The most economical way of saving this digestible food material is to feed the corn in the form of silage, consequently, the silo must figure prominently as a means of utilizing and marketing the corn crop.

FEATURES OF THE SILO

The prime object in silo construction is the preservation of feed in its natural succulent condition. This will require a building that will exclude the air which if allowed to enter will cause the silage to ferment and be spoiled for feed. To be efficient and durable, a silo needs to be constructed of suitable material and according to mechanical principles. Every farmer needs to consider the factor of economy before starting the silo for it happens frequently that sand, gravel and other material are at hand which will reduce the cost of erecting the more durable type of silo like the hollow block or the concrete. Often such structures may be erected with little outlay except for labor.

CAPACITY

The capacity of the silo depends upon two things — diameter and depth. It has been found that the silage keeps in deep silos better than in shallow ones. It is poor economy to construct a silo less than 20 feet deep. The deeper the silo the greater will be the amount of food stored per cubic foot, relatively less surface exposed to the air and the increased lateral pressure will force the silage against the walls of the silo so closely that less air will enter to cause loss by fermentation. The capacity of a silo is increased rapidly by enlarging the diameter for by increasing the diameter by half the capacity is doubled and doubling the diameter increases the capacity four times. The depth greatly influences the capacity for each ten feet from the top doubles the weight of the silage — thus the deeper the silo the more compact the material and the more perfectly it will be preserved.

LOCATION

The chief point to consider in locating the silo is convenience in feeding the silage. Silage is heavy material hence it is well to place the silo close to the barn and convenient to the feeding alley. Frequently, the silo is placed inside of the barn but this is not advisable as odors arising from the silage may contaminate the milk. An inside silo is not always convenient to fill and will occupy space that otherwise might be used to better advantage.

SIZE OF SILOS IN PROPORTION TO HERD

In planning the silo it is important to have the capacity which is governed largely by the diameter of the silo, in proportion to the size of the herd for when silage is fed from the surface at the rate of two or more inches per day very little loss will occur by fermentation even in hot weather. It is advantageous, frequently, to build two silos, one for winter and another for summer. The deep narrow silo gives the best grade of silage since more inches will be fed daily with less exposure.

In North Dakota the average length of time that silage may be fed profitably to cattle, ordinarily is from September until May or two hundred forty days. It is an excellent plan to supplement the pastures during the summer with corn silage especially in dry seasons. For this purpose, it is well either to build the silo large enough to furnish silage during the entire year or to have a large one for winter and a smaller for summer.

The quantity of silage fed to the average dairy cow per day is about forty pounds which would amount to nearly five tons for the period of 240 days. With beef cattle a somewhat smaller amount usually is fed. It is a satisfactory roughage for sheep and may be fed with advantage to idle horses in winter. It has the effect of softening work horses the same as grass. For hogs silage has little value. They will eat the grain and chew some of the stalks, but consume too little to make it a profitable feed for them. It makes a good succulent winter feed for poultry especially when made of alfalfa or clover.

If the stock are to be fed silage during summer when on pasture, one would need to allow about twenty pounds per day to supplement the grass. This would amount to an additional ton and a half per head making a total of six and a half tons per year for each cow.

Table A. indicates the number of cows, the quantity of silage and the number of acres of corn required to fill the silo. This estimate is made on the basis of the cows being fed at the rate of forty pounds per day for 240 days and the pasture supplemented during the summer months with twenty pounds of silage per day.

SIZE OF HERDS AND TONS OF SILAGE

TABLE A.

No. Cows	240 Days	Acres Corn	365 Days	Acres Corn
10	48 tons	10	65 tons	13
15	72 tons	15	65 tons	20
20	96 tons	20	130 tons	26
25	120 tons	24	172 tons	35
30	144 tons	29	195 tons	39
35	168 tons	34	227 tons	46
40	192 tons	39	260 tons	52
45	216 tons	44	292 tons	59
50	240 tons	48	325 tons	65

HOW TO USE THE TABLES

The first step in planning the silo is to determine the number of cows or their live stock equivalent and the probable number of days they will be fed. Turn to Table A and find the number of cows. The columns opposite will give the number of tons of silage required when forty pounds is fed daily for the number of days indicated. The other part of the table gives the quantity required when an additional twenty pounds is fed during the four summer months. In Table B will be found the corresponding number of tons with silos of different dimensions.

DIMENSIONS OF SILO AND CAPACITY IN TONS

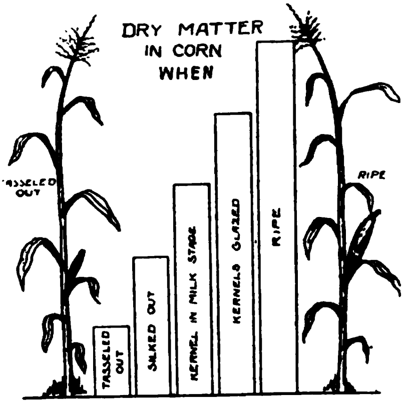
TABLE B.

Diameter Feet.		10	11	12	13	14	15	16	17	18	19	20
Depth Feet	20	26	32	38	44	51	59	67	76	85	94	105
" "	21	28	34	40	47	55	63	72	81	91	101	112
" "	22	30	36	43	51	59	67	77	86	97	108	120
" "	23	32	39	46	54	63	72	82	92	103	115	128
" "	24	34	41	49	57	66	76	87	98	110	122	135
" "	25	36	44	52	61	70	81	90	104	116	129	143
" "	26	38	46	55	64	74	86	97	110	123	137	152
" "	27	40	49	58	68	79	90	103	116	130	145	160
" "	28	42	51	61	71	83	95	108	122	137	152	169
" "	29	44	54	64	75	87	100	114	128	144	160	178
" "	30	47	56	67	79	91	105	119	135	151	168	187
" "	31	49	59	70	83	96	109	125	141	158	176	195
" "	32	51	62	74	86	100	115	131	148	166	185	205
" "	33	53	65	77	90	105	121	138	155	173	193	214
" "	34	56	68	80	94	109	126	143	162	181	202	224
" "	35	58	70	84	98	114	132	149	168	188	211	232
" "	36	60	73	87	102	118	136	155	176	196	219	242
" "	37	63	76	90	106	123	142	161	183	204	228	252
" "	38	66	79	94	110	128	148	167	191	212	137	262
" "	39	68	82	97	115	133	154	174	198	221	247	272
" "	40	70	85	101	119	138	160	180	205	229	256	281

TIME TO HARVEST CORN

The best silage is made from corn cut during the glazing stage. In case the season for frost has arrived it will need to be cut at an earlier stage for frosted corn soon becomes too dry to make good silage. Up to the tasseling stage of growth the corn plant builds framework and constructs cells to be filled with food material later. The growth of the corn plant is very rapid until it reaches the tasseling stage immediately after which begins the storing up of food material in the cells.

The storing of food material is rapid after tasseling time. The degrees of maturity are defined as follows: the tasseling, silk, milk, glazed and ripe stages of growth. Between tasseling and ripening, the quantity of water in the cells is replaced largely by sugar, starch and fats. The fololwing diagram indicates the increases in the relative amounts of food material stored in the corn plant at different stages of maturity.



SAME SIZE TASSELED OUT AS WHEN RIPE BUT NOTE DIFFERENCE IN FOOD VALUE
Palmer. N Dak Agr College

It has been found by experiment and chemical analyses that for each pound of dry matter at the tasseling stage there wil be two pounds when in silk, three pounds when in the milk, four pounds when in the glazing stage and five pounds when ripe. In other words there will be as much food material on one acre when ripe as are on four acres when tasseled out. Hence, the nearer the corn approaches the ripened stage the more food material will be obtained. The best grade of silage is secured when the corn is harvested in the glazed stage or when the kernels are well dented.

ACRES OF CORN TO FILL THE SILO

The number of acres of corn required to fiill the silo will depend upon the locality, the variations of the season and the variety of corn planted. Any of the flint or dent varieties will make good silage but the earlier maturing kinds are preferable. Corn planted in check rows so it can be cultivated both ways can be kept from weeds more easily. Data received from many practical farmers throughout the Northwest indicates that it is safe to estimate a yield of 4 to 5 tons of silage per acre.

FILLING THE SILO

The cost of filling the silo depends upon the length of haul and even distribution of help. A common arrangement of help is to have one man with three horses to cut the corn, two men to load the wagons in the field, three or more men with teams to haul the corn from the field to the silo depending upon the distance, one man to feed the cutter and one man to spread and pack the silage in the silo.

The average cost per ton of filling 31 silos, according to Farmers' Bulletin No. 292, Department of Agriculture, ranges from 46c to 86c with an average of 64c. In Iowa the cost ranges from 43c to 67c with an average of 50c while data from North Dakota farmers ranges from 50c to $1.31 with an average of 72c per ton.

HARVESTING MACHINERY

The handling of silage is best done by using a corn binder to cut the corn and tie it into bundles which saves much time and labor.

A low wagon with a strong rack saves unnecessary lifting and is a very satisfactory way of getting the green corn to the silo.

The silage is best cut into fine pieces not to exceed a half inch in length. Short pieces pack more firmly in the silo and live stock like it better and will eat it up cleaner. It is a good plan to have a large cutter with plenty of power to run it so that a large force can be worked in a rush season.

The cost of a corn harvester is about $125.00 and of a silage cutter $125.00 to $200.00 depending upon the size.

In some cases several farmers buy the machinery in partnership and exchange help at filling time. This enables them to fill the silo at the proper time even if help is scarce. The most economical way to fill the silo is to have a crew large enough to keep the engine and cutter working at full capacity. Where the silo is filled rapidly a good plan is to let the silage settle a day or two while another silo is being filled, then more silage can be put in and the full capacity of the silo utilized. The silage needs to be well packed near the walls for lateral pressure tends to develop friction against the sides of the silo and leaves spaces in the silage.

Rain does not harm the silage either before or after filling the silo. Often a threshing crew can be set to work filling the silo on a wet day when the grain is too damp to thresh. In case the corn is frosted a little before cutting, water will need to be added to the silage occasionally when filling to make it pack thoroughly and exclude air.

COVERING THE SILO

It is a good plan to have a roof on the silo. It need not be expensive but sufficient to keep out the snow and the rain. Many people prefer to leave the silo open and seal it by running on a quantity of chaff or straw. This is then saturated with moisture and seeded with grain which grows, forming a thick mat or covering, that prevents any loss of silage.

FREEZING OF SILAGE

The freezing of the silage does not injure its feeding value materially. Sometimes blankets are spread over the silage to prevent freezing. Where the silage is fed off each day and the surface kept even there usually is little difficffiulty except in extremely cold weather. If the frozen silage is broken from the walls and thrown into the center of the silo each day, it will usually be thawed out by the next feeding time.

TYPES AND MATERIALS

There are agreat many types of silos in use which are efficient, durable, and economical to construct. However, only representatives of the stave, the hollow block and the concrete types will be described here. Any of these types may be constructed by the average man from available material. The experience of many farmers who have built wooden silos indicates that such structures are less economical in the long run than those made of hollow blocks or concrete. The latter have the tdvantages of being fireproof, are not racked by the wind and need no repairs.

COST OF CONSTRUCTING VARIOUS TYPES WOODEN SILO

No.	Size	Capacity	Kind	Cost	Other Material	Labor	Total Cost	Cost Ton Cap.
1	16x36	155	Stave	$130.12	$47.80	$50.87	$228.78	$1.47
2	14x28	83	Panel	275.00	63.00	40.00	378.00	4.55
3	14x32	100	Stave	203.75	....	103.62	307.38	3.10
4	14x30	91	"	179.42	....	125.28	304.70	3.31
5	16x37	161	"	394.00	135.25	77.00	607.75	4.07
6	14x23	83	"	156.52	96.63	72.80	325.95	3.92
7	16x32	131	Panel	265.00	8.00	132.00	405.00	3.09
8	14x28	83	Stave	257.00	15.00	16.00	288.00	3.39
9	16x26	97	Panel	280.00	16.00	54.00	350.00	3.50
10	18x29	144	"	350.00	....	50.00	400.00	2.77
Average Cost and Cost per Ton Capacity							$359.55	$3.32

The object in compiling the data in these tables is to show the size, kind and cost of material, the cost of labor and the relative cost of the silo per ton capacity. The data compiled was obtained first hand from farmers throughout the Northwest who are using these various types of silos.

The above table includes data on homemade and patent wooden silos. In some instances considerable of the material used in making the roof, the chutes and staging was already on the farm which materially reduced the cost while in other cases the silo company furnished all of the material. In some instances the farmer was not obliged to hire any outside help and thus saved largely on the cash cost of construction.

HOLLOW BLOCK SILO

No.	Size	Cap.	Cost Blocks	Bags Cement	Cost	Other Material	Reinforcement	Cost	Labor	Total Cost	Cost Ton Cap.
1	17x35	168	$ 81.00	148	$53.28	$69.50		$17.50	$266.30	$525.03	$3.33
2	14x34	109	160.67	60	30.00	43.60		12.03	98.65	344.95	3.16
3	14x40	138	140.00	80	27.50	94.44	Old Rods	11.00	103.45	375.39	2.70
4	16x37	161	179.25	56	22.00	33.28	Iron Wire	14.00	90.63	329.16	2.28
5	15x44	184	142.70	..	60.00	25.00		12.00	108.00	347.70	2.23
6	14x37	123	90.70	40	24.75	11.60	Wire	11.60	102.20	239.85	1.95
7	16x35	149	148.75	100	37.79	41.50	Wire	13.75	115.00	356.79	2.39
8	14x38	128	98.00	50	22.50	25.30	Rods	12.20	60.00	218.20	1.70
	Average Cost and Cost per Ton Capacity									$343.13	$2.46

The data in this table includes only that of hollow clay blocks no data on cement blocks being included. The variation in cost of blocks per ton capacity is due somewhat to the size of the silo, the distance the blocks were shipped and the cost of freight. In some instances, wire and rods from an old wooden silo were put in for reinforcement but in most cases wire was used. The blocks are not difficult to lay and in a number of cases one mason and a helper was all the labor necessary.

MONOLITHIC CONCRETE SILO

No.	Size	Cap.	Bags Cement	Gost	Sand and Gravel	Other Material	Forms	Reinforcements	Labor	Total Cost	Cost Ton Cap.
1	16x33	143	208	$04. C0	$45.10	$9·85	$79.50	Wire and Iron	$132.48	$370.93	$2.17
2	14x31	96	152	98 80	45 50	34,25	37.62	Wire	92.70	409.97	3.22
3	16x34	143	156	87.90	94.50	44.75	....	Wire	104.00	331.15	2.31
4	16x31	125	196	22.50	5.00	55.45	49.50	Wire	154.00	396.45	3.09
5	14x32	100	132	86.00	102.00	55.17	33.50	Wire	87.00	365.67	3.63
6	16x24	87	168	135.20	....	93.00	....	Wire	90.00	318.20	3.65
Average cost and cost per ton capacity										$ 30.38	$3.12

This table shows a wide variation in cost of sand and gravel likewise in the cost of forms and labor. . Frequently a farmer had the sand and gravel on the farm while others were obliged to purchase it at quite an expense. In some cases the forms, were borrowed from a neighbor which reduced the expense.

In building the concrete silo the reinforcement used was woven wire-hog fencing—placed in position as indicated in figure 7.

In a few instances old irons were placed in the wall vertically to reinforce the silo against winds.

The variation of cost per ton capacity in any type of silo depends upon the amount of material already on hand and upon the amount of labor hired. One thing not to be overlooked in the tables is the depth of the silo in relation to cost per ton capacity. The deeper the silo the less the cost of construction per ton of capicity.

PIT SILOS

The pit or underground silo is used sometimes in localities where the soil is dry and does not cave in. A light wall of cement will hold and form an air tight silo. A serious objection to such a silo is the inconvenience in removing the silage. It will weigh on an average 40 pounds per cubic foot.

In such silos carbondioxide gas sometimes collects. This gas occurs in all silos during the first few days of filling if closed up tight. It is heavier than air, hence it collects in the pit silo or in other silos where the silage is left below the door over night.

Cases are reported where men have been suffocated by going into the silo at filling time where the doors had been closed tightly over night. A good precaution is to start the cutter and run in enough silage to mix the gas with air or lower a lighted latern into the silo before entering. If any gas is present the lantern will not burn.

STAVE SILOS

FOUNDATION—It is poor economy to erect a stave silo, or any other wooden construction, without placing it on a substantial foundation constructed from some material not subject to decay. Experience has shown that when stave silos are placed directly on the ground they not only settle and sag unevenly, causing a high percentage of loss in the silage, but the lower ends of the staves decay so rapidly that its period of usefulness is reduced to a few years at best.

If the surface of the ground where the silo is to be located is level and smooth the foundation may be easily marked out as shown in figure 1. Drive a stout stake in the center of the proposed silo and at the height desired for the foundation which should be at least one foot above the ground line. By means of a radial sweep, made from a straight two by four pivoted on the central stake by a large spike and carrying a marker as shown in figure 1, the outside circle of the foundation may be traced on the ground. The marker is next moved in on the sweep a distance equal to the desired thickness of the foundation wall when the inner circle of the foundation wall may be traced.

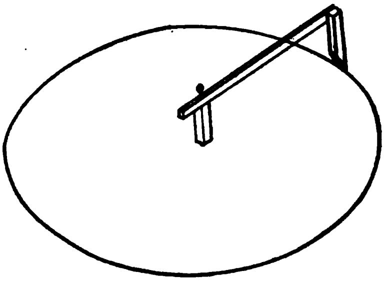


Figure 1

If the foundation is to be constructed from concrete it should be from 8 to 10 inhes thick for medium sized silos and should preferably extend below the frost line. The earth between the lines, traced on the ground, that mark the inside and outside of the foundation should be carefully excavated, leaving the sides perpendicular and the bottom level.

If sharp and clean sand and gravel are available a good concrete foundation may be made from a proportion of 1 part cemet, 2 1-2 parts sand and 5 parts gravel. The concrete must be well mixed and should contain enough water so that when rammed into the trench by means of a tamper, water will stand on the surface. When the trench has been filled to the surface of the ground, forms must be constructed to carry the foundation to the desired height above the surface. These may be cheaply constructed by driving two by four stakes half an inch from the foundation and two feet apart along the inner and outer circle of the foundation. After the stakes have been driven they should be sawed off at the desired height and so that the top of the foundation will become level. This can be easily accomplished by pacing a carpenter's level on the sweep used in tracing the foundation when it may be swung around and the height of each stake marked. The wall of the forms can be made by nailing half inch boards 6 inches wide on the stakes. Green lumber will be best for this purpose as it will bend more easily but if it is not readily obtainable, seasoned lumber that has been soaked in water will serve the purpose equally well.

One of the main objections to stave silos has been their lack of rigidity and that when empty they are often blown off their foundations and wrecked by high winds. This objection may be largely overcome by securely anchoring them to the foundation which may be done by placing four or more half inch eye bolts about 18 inches long in the foundation to which the silo may be anchored. They should be placed near the outer edge of the foundation and held in place while the forms are being filled, by a board placed across the top of the form.

The foundation should be of such size that its inside wall will be flush with the inside wall of the silo as shown in the left of figure 2. If it is allowed to project into the silo as shown in the right of the figure it will prevent the silage from settling properly with the result that considerable silage may become spoiled.

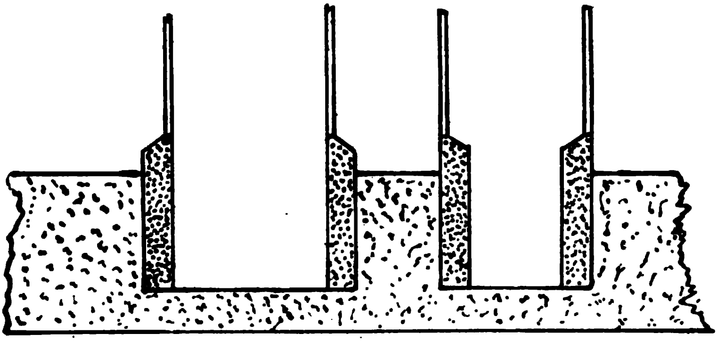


Figure 2

The top of the foundation should be finished with a concrete made from 1 part cement and 3 parts sand, troweled smooth and slightly beveled as shown in figure 2.

When the concrete has set sufficiently the earth inside the foundation should be excavated to a depth 4 inches above the bottom of the wall and if the excavation of the trench was done carefully the wall will be made sufficiently smooth by applying a thin coating of cement and water with a trowel or white wash brush.

THE FLOOR—If the soil is firm and well drained a concrete floor is not necessary. Still such a floor makes the silo easier to clean and excludes rats and mice which otherwise may burrow under the wall and gain access to the silage. Ordinarly a concrete floor is desirable and should be put in. A good concrete floor may be made from the same proportions of sand and cement as the foundation and should be 4 inches thick and surfaced with a concrete made from 1 part cement and 3 parts sand.

THE STAVES—Material for staves may be secured from local lumber dealers or may be ordered from companies who make a specialty of manufacturing stave silos. Cypress, white pine, cedar and redwood are good material for staves and should be selected stock so as to be free from sapwood and loose knots and should be straight with perfect edges. It is desirable that each stave be in one piece but where joints are necessary they should be made by inserting a galvanized iron spline as shown in figure 3. Care should be taken that the joints are well distributed so as not to unduly weaken the silo.

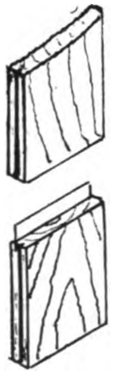


Figure 3

CONCRETE SILOS

FOUNDATION—The foundation for a concrete silo may be constructed in the manner indicated for stave silos except that at a point one foot from the bottom of the foundation and below this the excavation should be widened so as to permit of a footing 2 feet wide and 1 foot deep to carry the heavy walls. 1 part cement, 2 1-2 parts clean, sharp sand and 5 parts gravel will make a good foundation and with average material and good mixing is sufficiently rich for the entire structure. The reinforcing rods or woven fence wire must be imbedded in the foundation a distance of 8 inches so that no weakness occurs at the junction of the wall and foundation.

THE FLOOR—may be constructed as indicated for stave silos.

FORMS—The forms described and illustrated herein are simple to construct and easy to manipulate. Forms similar to these have been employed with success in a large number of silo constructions and are believed to be as cheap and satisfactory as any now in use. Forms of this type can be contsructed at a cost of from twenty-five to fifty dollars, depending upon the size of the silo and the price of materials, and instances are recorded where they have been made at a cash outlay of only fifteen dollars. These forms may be used in constructing a large number of silos so that they may often be disposed of at a slight discount for wear and tear.

The inner form is made in 8 sections as shown in figures 4 and 5. It consists of 16 segments made of 2 x 12 inch plank, 16 cleats made of 2 x 6 inch plank, 1 x6 inch matched flooring. No. 28 gauge galvanized sheet steel, and 64 1-2 inch bolts 4 1-2 inches long.

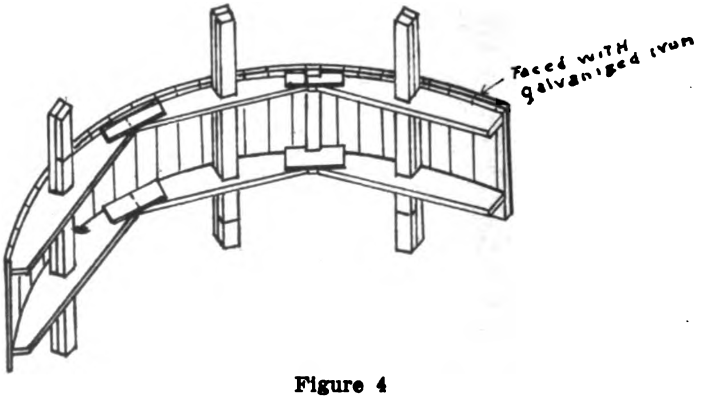


Figure 4

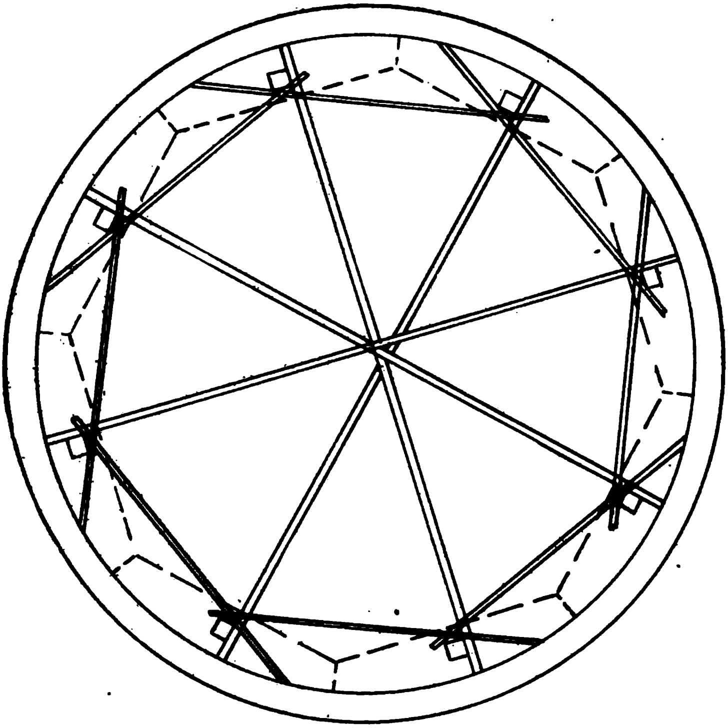


Figure 5

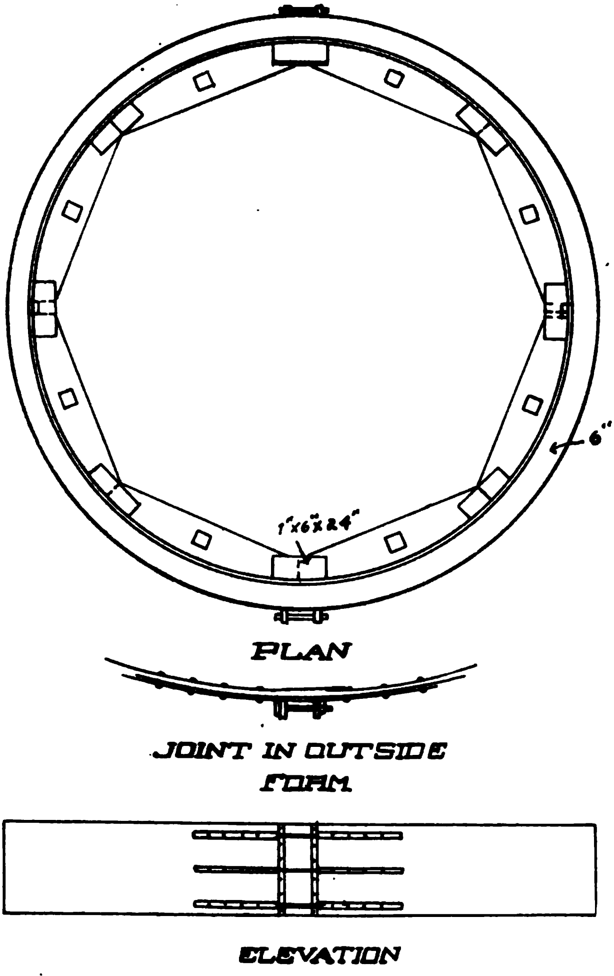
To design a pattern or template with which to mark out the sixteen segments constituting the framework of this form first draw on a piece of paper a circle about one foot in diameter. Carefully space off the circumference into eight equal distances. This may be done by first dividing the circle into four equal parts and next bisecting the arc of the quadrants or parts by means of a compass. Now place this circle on a level floor and secure a light but straight wooden sweep slightly exceeding in length the desired radius of the silo and pivot it on a nail driven through the center of the circle and into the floor. Fasten to the sweep a pencil or sharp scratch awl at a distance from the center equal to 1 inch less than the radius of the silo. Place a thin board or piece of paper under the marker and describe on it the arc of a circle by revolving the sweep on its pivot. Next place one edge of the sweep carefully along one of the marks made on the circumference of the small circle and using the edge of the sweep as a guide mark off in a radical direction one end of the pattern. Then place the sweep on the next point on the circle and mark off in a radical direction the other end of the pattern. This pattern is next cut out and forms a template for marking out the segments. If care is taken in executing the work as described the segments will, when assembled, form two perfect circles of a diameter 2 inches less than the inside diameter of the silo and when inch flooring is nailed on the form will have the required size.

The 1 x 6 inch flooring is sawed up into 3 foot lengths and nailed to the outer edges of the segments, the latter being placed 2 feet apart center to center. The boards are covered with galvanized sheet metal and the eight sections of the form thus made are held together with 2 x 6 cleats 2 feet long, cut to the same circle as the ribs, so that the assembled form makes a true circle. The 64 1-2 inch bolts, previously mentioned, are used for holding the sections together—four bolts being used for each cleat. The form is tightened by means of two keys, placed directly opposite, as shown in the plan and perspective figures 4 and 5. The keys are made of 2 x 4's 3 feet long and have a slight taper. The keys should be driven down after the form is bolted together.

By reference to the figures it will be noticed that each segment has a hole 4 inches by 4 1-2 centrally located, through which pass a 4 x 4 upright made by nailing two 2 x 4's together. Half inch holes are drilled in these uprights at intervals of two and one half feet, corresponding holes on all uprights being at the same level. When the form is raised bolts are inserted in the holes immediately under the bottom segments of the form and as the work progresses upward additional 2 x 4's are spliced on alternately.

As the inner form is moved upwards it is necessary to brace the upright supports. This may be done as shown in figure 5 which shows a view of the form underneath. The bracing between adjacent uprights is put on every five feet and for this purpose 1 x 6 inch boards nailed on horizontally with one end firmly against the silo wall, as shown, may be used. Every fifteen feet 2 x 4 or 2 x 6 braces should be run across to opposite uprights—care being taken that the ends of the braces fit snugly against the wall of the silo.

The outside form is made in halves from No. 18 gauge galvanized sheet steel 3 feet wide. The two joints in the form are made by three strips of heavy band iron rivited on each side of the joint, bent out at right angles near the



PLAN

JOINT IN OUTSIDE FORM

ELEVATION

Figure 6

joint and provided with holes for half inch bolts which are threaded to permit loosening and tightning when the form is raised. These joints are clearly shown in figure 6. A heavy wire handle is put on the outside form opposite each pair of 4 x 4 uprights for the purpose of raising. To each handle is fastened a 3-8 inch rope 6 feet long. This rope is run over a little bracket which slides up and down the uprights.

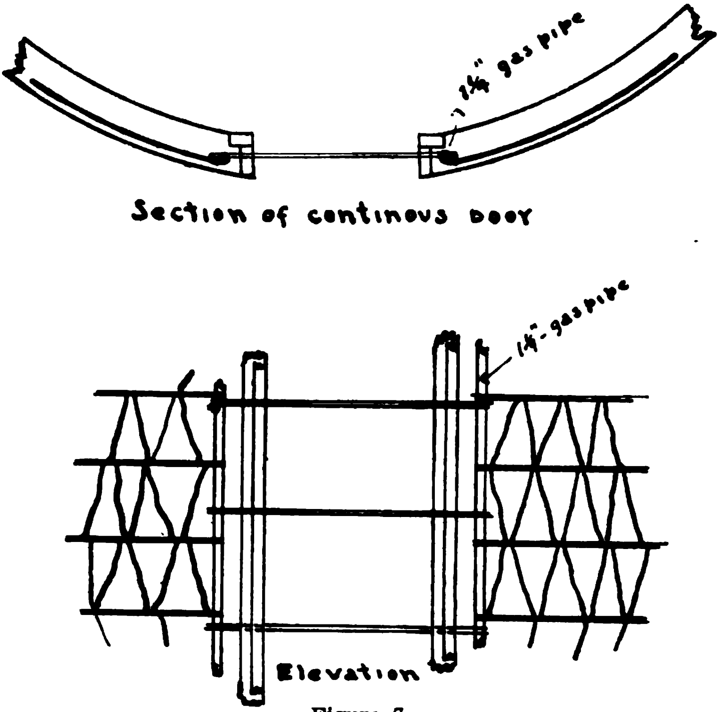


Figure 7

Figure 7 shows a section and an elevation of a continuous door and the method of reinforcing the concrete with woven fene wire.

THE DOOR—The reinforcement must be continuous and extend clear around the silo or the construction may spread at its weakest point which is usually near the doorway. This weakness is overcome in this plan by the use of two 2-inch gas pipes as shown in figure 7. Holes large enough to receive 3-4 inch rods are drilled in both pipes in the same relative position at interals of 12 inches. Through these holes 3-4 insh stay rods are placed as shown in the figure. These stay rods also form a convenient ladder for gaining access to the silo; the door may be fastened to them by means of 1-2 inch hooked bolts that pass through the door planks and hook over the rods—being tightened from the inside by means of burs. The frame of the doorway is made from two 2 x 4's spiked together, in the form of an L, and placed 2 feet 6 inches apart as shown in section figure 7.

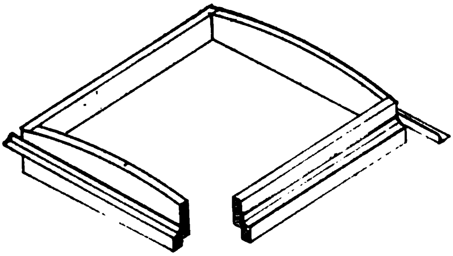


Figure 8

REINFORCEMENT—Figure 7 also shows the method of reinforcing the concrete by means of woven fence wire. A medium to heavy weight, coarse mesh fence wire three feet wide is best suited for this purpose. As each course is 2 1-2 feet high this will allow the wire to overlap 6 inches in each course. The wire should be placed about one inch from the outer form or as close to it as is safe without danger of exposing the wire. Care must be taken to securely fasten the ends of the wire to the gas pipes. This may be easily accomplished by simply wrapping the wire around the pipes and twisting each wire back upon itself.

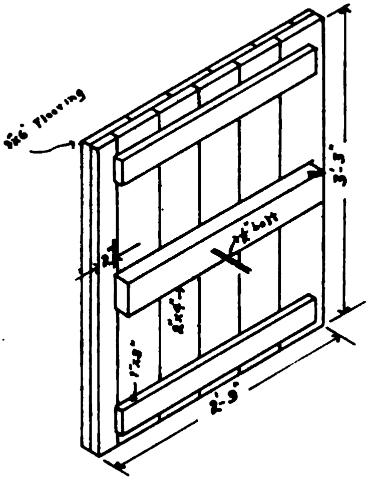


Figure 9

NON-CONTINUOUS DOORS—If non-continuous doors are desired the form for the doorway may be constructed as indicated in figure 8 and the door as illustrated in figure9.

The bottom and top pieces of the form are made of 2 x 6 inch plank cut to the arc of a circle with a diameter equal to the outer diameter of the silo wall. The two sides are made of 2 x 4,s. A frame of lighter material is placed around the outside of the form for the purpose of making a recess two inches deep around the opening on the inner side of the wall, into which the door will fit. This frame is tapered to permit removal from the wall as soon as the concrete has hardened and may be used again for the next doorway above.

The construction of the door is clearly shown in figure 9 and it is believed, needs no further explanation.

HALLOW BRICK AND CONCRETE BLOCK SILOS

Hollow brick silos are popular in cold climates because of the greater security against freezing provided by the hallow wall. The cost of these silos is often slightly in excess of the monolithic concrete construction although instances are numerous where they have been erected at a cost less than that for which a concrete silo could be erected in the same locality. Comparative costs will depend upon the price of materials at the place where the silo is to be built.

FOUNDATION—The same type of foundation discussed for concrete silos will be found available for this form of silo.

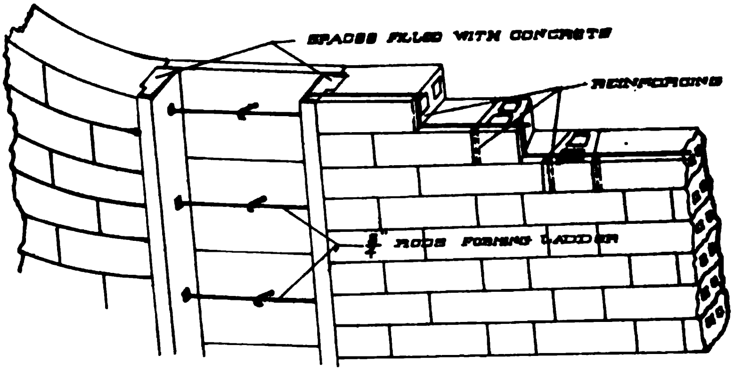

SPACES FILLED WITH CONCRETE
REINFORCING
$\frac{1}{4}$" RODS FORMING LADDER

Figure 10

REINFORCING—Failures reported with this type of silo have been largely due to lack of reinforcement or the use of poor mortar. Figure 10 shows a perspective of a section of a hollow interlocking brick silo. Figure 11 shows the plan of one of the tappered interlocking blocks used alternately with rectangular blocks as shown in figure 10. The figure further shows a continuous doorway made by using two 4 inch 5 1-4 pound steel channels. The reinforcing wires laid in the mortar between the courses of block, as shown, must be securely fastened to the channels. The space between the channels and the brick is filled with mortar as the wall is being erected.

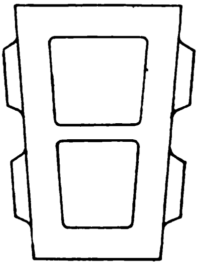
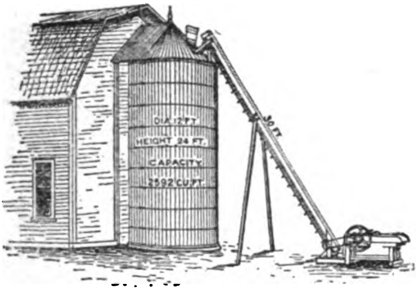


Figure 11


DIA. 12 FT.
HEIGHT 24 FT.
CAPACITY
2592 CU. FT.
30 FT

der much after the manner of attaching the modern binder engine. The field was so soft, however, that the grain wheel would sink into the soil to such an extent as to cause the platform to drag on the ground and to overcome this difficulty a 4x4 inch timber was fastened to the rear wagon axel in the form of a cantilever supporting the binder platform by means of a chain as shown in the figure. Over 150 acres of grain, much of it in standing water and the entire field so wet that the ordinary binder would clog immediately, was successfully cut with this makeshift device.

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NORTH DAKOTA AGRICULTURAL COLLEGE

North Dakota

GOVERNMENT AGRICULTURAL EXPERIMENT STATION
OF
NORTH DAKOTA

BULLETIN NO. 100

CROPPING SYSTEMS FOR WHEAT PRODUCTION

BY

J. H. SHEPPERD and R. C. DONEGHUE

Any farmer, teacher or student in the State may have this bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
OCT, 1912

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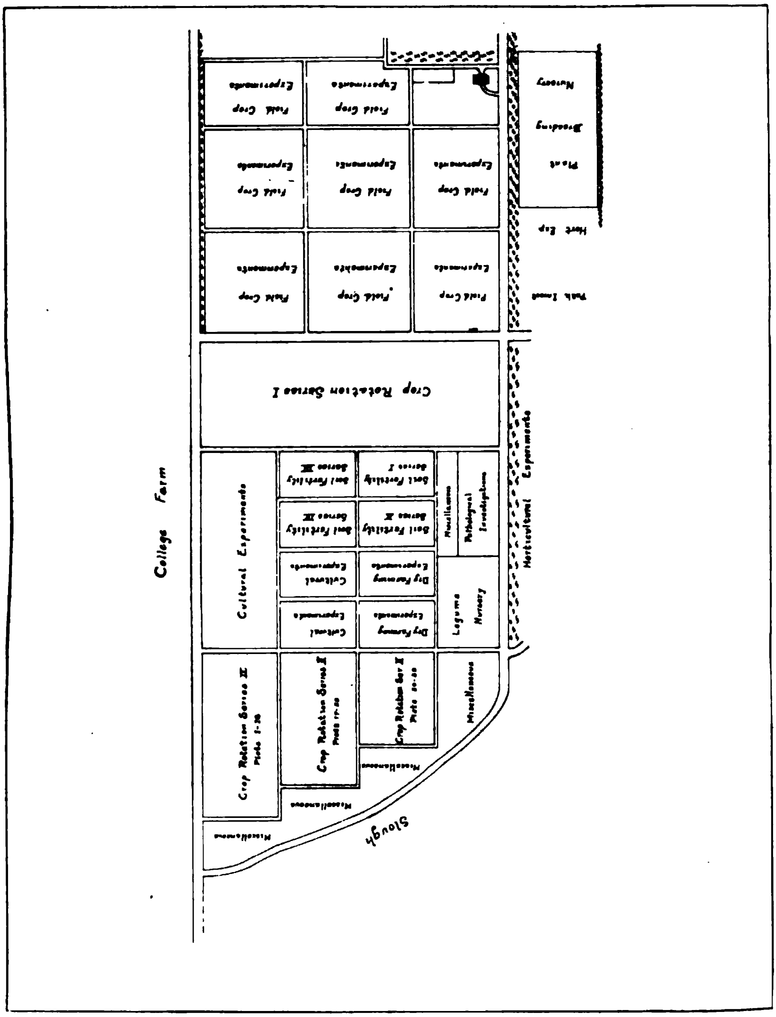

Plate I. Map of area used for Agronomy Investigations.

Cropping Systems for Wheat Production

The acreage of wheat in North Dakota exceeds that of any other crop and the sale of wheat furnishes the principal source of income to the farmers of the state. The men who settled in the state first found that the soil and climatic conditions were such that a good yield of spring wheat of high quality could be produced. The extreme eastern part of the state known as the Red River Valley was settled first and the appearance of the soil and the yields secured led the early settlers to believe that the soil was inexhaustible and that it could be cropped continuously to wheat for an indefinite period.

That these ideas were erroneous has been proven by numerous investigations and the experience of practical farmers. However, the soil of the Red River Valley contains a large amount of the elements of plant food. The following table compiled from analyses made by the Department of Chemistry and published in publications (1) of this station shows the amount of the principal plant food elements in the localities indicated.

Table No. I.—**Composition of Typical Soils of the Red River Valley in North Dakota.**

Pounds per acre in two million (about 7 inches).

Locality	Total Nitrogen.	Acid Soluble			
		Phosphorus	Potassium	Calcium	Magnesium
Bathgate	7560	1460	11560	18880	14360
Fargo	7200	2520	13600	19860	6020
Wahpeton	5520	1040	6540	11800	7940
Average	6760	1673	10566	16846	9440

These samples were taken from fields that are representative of the Red River Valley. The samples from Bathgate and Wahpeton were taken from the State Demonstration Farms, and the Fargo sample is from Plot 2 Rotation Series No. 1 on the Experiment Station grounds. It is evident that these soils are well supplied with the important elements of plant food. It will be noted, however, that there is a much smaller supply of phosphorus than any other element. However, this is true of practically all common soils. For example, this soil compares very favorably in phosphorus content with some of the richer soils of the corn belt. Hopkins and Pettit have made a thorough study of the composition of soils in relation to crop growth and their conclusions are:

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(1) Page 26, Twelfth annual Report, N. D. Agr. Exp. Sta., Page 49, Ninth Biennial Report of the N. D. Agr. College and Exp. Sta., Page 32 Twenty-first annual Report of the N. D. Agr. Exp. Sta.

"In studying the composition of different soils it is well to keep in mind that our most productive soils of normal physical composition contain in the surface seven inches per acre about 8000 pounds of total nitrogen, 2000 pounds of total phosphorus and about 30,000 pounds of total potassium." (1).

In their studies they have made determinations of both the acid soluble and total phosphorus and potassium. They concluded from the study of a large number of analyses that

"As an average strong hydrochloric acid (official method A. O. A. C.) dissolves 85 per cent of the total phosphorus but only 25 per cent of the total potassium, with large variations, however, in each case." (2).

Using the above estimates as a basis we have in the following table a comparison of the average analyses of the black clay soil of the Red River Valley with the most productive soils of Illinois.

Table No. II—**Comparison of the composition of the Red River Valley black clay soil with the average of very productive soils.**

Pounds per acre in 2 million of soil (0.7 inches).

Locality	Total Nitrogen	Acid Soluble	
		Phosphorus	Potassium
Average Red River Valley Black clay soil	6760	1673	10566
Average of most productive Ill. soils	8000	1700	7500

(1) Page 195 Bulletin 123 Illinois Agr'l Experiment Station.
(2) Page 260 Bulletin 123 Illinois Agr'l Experiment Station.

That the black clay soil of the Red River Valley contains a comparatively large amount of the important elements of plant food is evident. The soils used in making these analyses have been cropped in much the same manner as the average farm in the Red River Valley. At the time the sample was taken from Plat 2 Rotation Series No. 1 it had grown at least 19 successive wheat crops. The other samples were taken from land that previous to its use as a demonstration farm had been cropped by farmers without any special effort to maintain its fertility. In their virgin state these soils would have no doubt shown a higher percentage of the important elements than some of the most productive lands of the corn belt.

It is evident, therefore, that our problem is not one of building up worn-out lands but of making the best use of an adequate supply of plant food supplementing it as much as possible with manures in order that this supply may be maintained for future production. Briefly this will be accomplished by thorough tillage, drainage, proper rotation of crops and the rational use of manures.

Realizing the importance of the proper arrangement of crops in a rotation the North Dakota Experiment Station began a series of experiments in 1892 to determine the influence of various crops in cropping systems for wheat production. The following quotation from Bulletin No. 10 by Prof. W. M. Hays then Agriculturist at this Station furnishes a fairly good description of the land on which the experiment was started.

"In the spring of 1892 twenty nine plots containing one acre each, two by eighty rods with twelve feet alleys between, were laid out to test various rotations of crops. The forty acres of land (N. E.¼ of S. E.¼ of Section 36) chosen for this experiment is typical Red River Valley soil. It is nearly level but slants very slightly to the east and north and along the sides good road ditches have been constructed furnishing thorough surface drainage.—This piece of land is as nearly uniform as far as the eye can judge, as any forty acres of land I ever saw and offers a very exceptional opportunity for this kind of an experiment.—Analyses by Prof. E. F. Ladd show that the surface soil taken at several places on this farm is so nearly alike that the differences are practically nothing. In physical condition there is a very slight and gradual change to a heavier more "gumbo" like nature from the southwest toward the northeast corner. The land was broken about 1882 and had borne continuous crops of wheat until 1892."

In 1894 the plots were cut down to one third acre in size by cutting off the west end so that they were one-third the original length. Six new plows were made from the cut-off portions of some of the original ones in order that a study of cropping systems for flax might be made.

Reports of progress have been published in Bulletins Nos. 10, 11, 23, 39 and 48 and in the annual reports of the Experiment Station for 1897 and 1898.

The original purpose was to determine the influence of various crops, and the cultivation incident to their production, upon the yield of succeeding crops of wheat. For this reason wheat is the most prominent crop in all of the rotations. The rotations were of three, four, five, six, and seven years. Plats 1, 2, 14, 19, 24 and 25 were to be cropped to wheat continuously. In 1900 some of these plots had become so weedy that it was thought best to retain only plot 2 as a continuous wheat plot. Plot 1 was seeded to brome grass the following year and has been kept in brome grass continuously since that time. In 1901 plot 30 was set aside for pathological investigations and in 1903 plot 31 and in 1907 plot 32 were set aside for the same purpose. The original rotations were discontinued in 1907 and all of the plots except plots 1, 2 and 35 were fallowed to clean the land of weeds. In the fall of 1908 all except these three plats were seeded to winter rye which was harvested the following summer (1909). In 1910 a new scheme of cropping was outlined in which the rotations are more complete than were the original ones.

As far as possible the original plan of cropping has been followed. In some cases climatic conditions have been such that the cropping has been modified slightly. For this reason the data is not as complete as might be desired. This tract of land like much of the Red River Valley has rather poor natural drainage and at times the best surface drainage that could be provided was not adequate for the removal of excess water. This has also interfered with the proper execution of details at times and thereby caused some deficiencies in the records.

In order to summarize the cropping on each plot the following outline is given.

Plot No. 1. Original plan, continuous wheat. It was continued as such until 1901 when owing to its extreme weediness it was seeded to brome grass. The land was so weedy, however, that a very poor stand was obtained and it was plowed up and seeded the following year. It has been in brome grass since that time and since 1905 an annual application of five loads of manure has been applied to the west half of the plot.

Plot No. 2. Original plan, wheat continuously. This plot has been seeded to wheat every year since the experiment was started, and has been cropped continuously to wheat since 1882, according to verbal statement made to Hays and Shepperd respectively by James Holes and Geo.

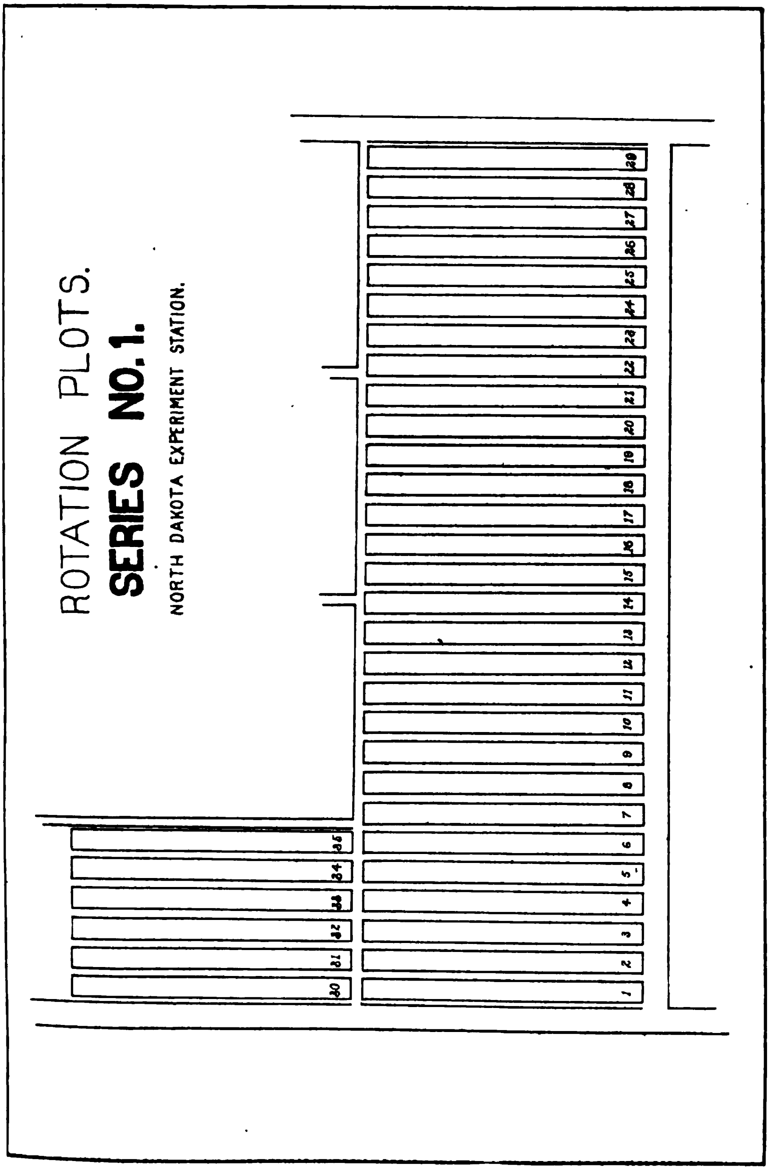
ROTATION PLOTS.
SERIES NO. 1.
NORTH DAKOTA EXPERIMENT STATION.
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Plate II.

Osgood of Fargo, North Dakota, who had known the land from the first settlement of the country.

Plot No. 3. Original plan, two years of timothy followed by four years of wheat. This was continued until 1907.

Plot No. 4. Original plan, one year bare fallow followed by three years of wheat. Continued until 1907.

Plot No. 5. Original plan, one year of corn followed by three years of wheat. Continued until 1907.

Plot No. 6. Original plan, one year of corn manured with six loads of rotten manure per acre followed by three years of wheat. Continued until 1907.

Plot No. 7. Original plan, field peas one year followed by three years of wheat. Continued until 1907.

Plot No. 8. Original plan, field peas plowed under one year followed by three years wheat. Continued until 1907.

Plot No. 9. Original plan, millet one year followed by three years of wheat. Continued until 1907.

Plot No. 10. Original plan, millet manured with six loads of rotten manure one year followed by three years of wheat. Continued until 1907.

Plot No. 11. Original plan, millet plowed under one year followed by three years of wheat. Continued until 1907.

Plot No. 12. Original plan, rape one year followed by three years of wheat. Continued until 1907.

Plot No. 13. Original plan, mangels one year followed by three years of wheat. Continued until 1907.

Plot No. 14. Original plan, continuous wheat. Continued until 1900 when it was fallowed to clean the land of weeds. In wheat in 1901, 1902 and 1903. Fallow in 1904 and in wheat in 1905 and 1906.

Plot No. 15. Original plan, fallow one year followed by three years of wheat. Continued until 1906.

Plot No. 16. Original plan, wheat one year; timothy and clover meadow, two years; wheat, two years; barley, one year. Continued until 1907.

Plot No. 17. Original plan, wheat one year; clover two years; wheat two years; barley one year. On account of winter killing of the clover some deviation from the original plan has been necessary. In 1894 it was seeded to wheat and was fallowed in 1896. In 1906 it was seeded to flax. Aside from these changes it was continued until 1907.

Plot No. 18. Original plan, wheat three years; peas, one year; wheat, one year; clover, two years. On account of the winter killing of clover and the failure to secure a stand some changes were necessary. In 1895 it was fallowed and in 1901 and 1902 was in wheat in the place of clover and in 1903 was in clover in place of wheat. In 1906 it was in wheat in the place of peas.

Plot No. 19. Original plan, wheat continuously, two or three pounds of clover seeded in wheat annually. Continued until 1900 when it was fallowed to clean the land of weeds. In wheat in 1901, in brome grass in 1902 and 1903, in flax 1904 and wheat in 1905 and 1906.

Plot No. 20. Original plan, potatoes one year followed by three years of wheat. Excepting 1892 when this plot was fallow the rotation as outlined was continued until 1907.

Plot No. 21. Original plan, spring rye. one year; wheat, two years. This plan was continued until 1901 when corn was planted in order that the land might be cultivated to clean it of weeds. Flax was seeded in 1902; wheat in 1903 and 1904; corn in 1905 and flax in 1906.

Plot No 22. Original plan, barley, one year; wheat, two years. This was continued until 1907 with the exception of 1905 when it was fallowed.

Plot No. 23. Original plan, oats, one year; wheat, two years. This plan was followed until 1900 when it was fallowed to clean it of weeds. Seeded to flax in 1901; wheat in 1902 and 1903; potatoes in 1904; flax in 1905 and wheat in 1906.

Plot No. 24. Original plan, wheat continuously. Continued until 1900 when it was fallowed to clean it of weeds. Seeded to wheat in 1901 and 1902; clover and timothy in 1903; flax in 1904; fallow in 1905 and wheat in 1906.

Plot No. 25. Original plan, wheat continuously. Continued until 1900 when it was fallowed to clean the land of weeds. In brome grass in 1901 to 1903 and wheat 1904 to 1906.

Plot No. 26. Original plan, bare fallow, one year; wheat, three years. Continued until 1907. The results in 1895 and 1897 were vitiated to some extent owing to the drifting of soil on to the plot. The data for these years are presented as a matter of record.

Plot No. 27. Original plan, timothy, two years; wheat, three years. Continued until 1901 when it was seeded to broom corn millet. In wheat in 1902 and 1903. Broom corn millet in 1904 and wheat in 1905 and 1906. The drifting of soil caused damage similar to that noted for plot No. 26.

Plot No. 28. Original plan, timothy, three years; wheat, four years; continued according to plan until 1907 excepting 1903 when the plot was in timothy in place of wheat. The drifting of soil also caused some damage in the years noted for plot No. 26. The records of timothy yields are rather incomplete.

Plot No. 29. Original plan, flax, one year; fallow, one year; wheat, two years. Continued until 1907.

Plot No. 30. Original plan after 1893, flax continuously. Continued until 1901 excepting 1897 when it was seeded to wheat by mistake. After 1901 was set aside for pathological investigation.

Plot No. 31. Original plan after 1893, flax, one year; wheat, one year. Continued until 1903 when it was set aside for pathological investigations.

Plot No. 32. Original plan, beginning 1895 wheat, one year; fallow, one year; flax, one year; wheat, one year. Continued until 1907 when it was set aside for pathological investigations.

Plot No. 33. Original plan beginning 1894, flax, one year; wheat, two years. Continued until 1905 when it was fallowed. In wheat in 1906.

Plot No. 34. Original plan beginning 1894, wheat, two years; flax, one year; corn, one year. Continued until 1907 excepting 1897 when wheat was seeded by mistake when corn should have been grown.

Plot No. 35. Original plan beginning 1894, wheat, one year; flax, one year; corn, one year. Continued until 1905. Seeded to flax in 1905 and 1906.

The cropping and yields per acre are summarized in Table No. III.

TABLE III.—Crop Rotation Experiments—Series. No. I.—Yield for the First Four Year Period.

1892		1893		1894		1895		Average Yield of Wheat for Period
CROP	YIELD	CROP	YIELD	CROP	YIELD	CROP	YIELD	
1 Wheat	21.6	Wheat	8.2	Wheat	20.00	Wheat	24.00	18.42
2 Wheat	19.3	Wheat	10.0	Wheat	21.75	Wheat	23.00	18.51
3 Wheat	21.1	Timothy	1.04 T.	Timothy	1.2 T.	Wheat	19.00	20.02
4 Fallow		Wheat	11.8	Wheat	23.75	Wheat	23.50	19.68
5 Corn	.92 T. 33.0	Wheat	14.4	Wheat	25.00	Wheat	24.00	21.13
6 Corn-Man	1.0 T. 37.5	Wheat	17.2	Wheat	24.75	Wheat	25.00	22.31
7 Field Peas	10.5	Wheat	14.4	Wheat	23.50	Wheat	23.00	20.30
8 Field Peas Plowed under		Wheat	10.4	Wheat	21.66	Wheat	23.00	18.35
9 Millet	1.97 T.	Wheat	13.3	Wheat	23.66	Wheat	23.00	19.98
10 Millet	2.00 T.	Wheat	15.1	Wheat	25.50	Wheat	23.00	21.20
11 Millet Plowed under		Wheat	14.1	Wheat	22.75	Wheat	23.50	20.11
12 Rape	5.5 T.	Wheat	19.6	Wheat	26.25	Wheat	26.00	23.95
13 Mangels	7.5 T.	Wheat	18.5	Wheat	26.33	Wheat	20.50	21.77
14 Wheat	21.1	Wheat	8.1	Wheat	20.25	Wheat	22.50	17.98
15 Fallow		Wheat	16.0	Wheat	25.75	Wheat	24.50	22.08
16 Wheat	19.6	Timothy and Clover	1.03 T.	Hay	1.61 T.	Wheat	31.00	25.30
17 Wheat	19.6	Clover	.85 T.	Wheat	20.66	Fallow		20.13
18 Peas	8.6	Wheat	12.9	Clover	1.50 T.	Fallow		12.90
19 Wheat	20.0	Wheat	11.8	Wheat	22.62	Wheat	24.50	19.73
20 Fallow		Wheat	19.6	Wheat	25.62	Wheat	25.00	23.40
21 Spring Rye	13.2	Wheat	10.6	Wheat	18.50	Spring Rye	18.30	14.28

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for First Four Year Period (Con't.)

22 Barley	29.0	Wheat	6.4	Wheat	18.50	Barley	13.00	12.45
23 Oats	75.0	Wheat	10.1	Wheat	18.00	Oats	41.50	14.05
24 Wheat	19.4	Wheat	8.6	Wheat	18.33	Wheat	23.50	17.45
25 Wheat	17.3	Wheat	9.5	Wheat	15.50	Wheat	23.00	16.32
26 Fallow		Wheat	14.1	Wheat	21.00	Wheat	25.20	20.10
27 Wheat	17.3	Timothy	1.01 T.	Timothy	1.30 T.	Wheat	27.00	22.15
28 Wheat	13.3	Timothy	.94 T.	Timothy	1.61 T.	Timothy		13.30
29 Flax	Not recorded	Fallow		Wheat	14.50	Wheat	25.00	19.75
30 Wheat	19.4	Wheat	8.6	Flax	9.50	Flax	12.62	14.00
31 Wheat	17.3	Wheat	9.5	Flax	8.50	Wheat	13.50	13.43
32 Fallow		Wheat	14.1	Timothy	1.40 T.	Wheat	17.00	15.55
33 Wheat	17.3	Timothy	1.01 T.	Flax	10.50	Wheat	23.00	20.15
34 Wheat	13.3	Timothy	.94 T.	Wheat	24.62	Wheat	22.50	20.14
35 Flax	Not recorded	Fallow		Wheat	25.33	Flax	8.50	25.33

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for the Second Four Year Period.

1896		1897		1898		1899		Average Yield of Wheat for Period
CROP	YIELD	CROP	YIELD	CROP	YIELD	CROP	YIELD	
1 Wheat	16.14	Wheat	13.1	Wheat	27.10	Wheat	22.44	19.69
2 Wheat	17.9	Wheat	15.0	Wheat	25.14	Wheat	18.83	19.21
3 Wheat	Not recorded	Wheat	18.6	Wheat	29.69	Timothy		24.14
4 Fallow		Wheat	21.1	Wheat	31.51	Wheat	22.94	25.18
5 Corn		Wheat	21.0	Wheat	29.84	Wheat	18.06	22.96
6 Corn		Wheat	20.7	Wheat	32.35	Wheat	22.26	25.10
7 Field Peas	24.75	Wheat	20.4	Wheat	25.77	Wheat	19.19	21.78
8 Field Peas Plowed under		Wheat	12.9	Wheat	26.80	Wheat	21.08	20.26
9 Millet	1.44 T.	Wheat	20.3	Wheat	29.36	Wheat	20.91	23.52

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for the Second Four Year Period (Cont.)

10	Millet	1.38 T.	Wheat	22.9	Wheat	31.34	Wheat	23.49	25.91
11	Millet Plowed under		Wheat	17.0	Wheat	29.00	Wheat	19.58	21.86
12	Rape { Green Dry	13.96 T. 1.63 T.	Wheat	21.2	Wheat	26.06	Wheat	19.68	22.11
13	Mangels	*	Wheat	21.1	Wheat	25.43	Wheat	20.21	22.24
14	Wheat	15.83	Wheat	17.6	Wheat	14.38	Wheat	14.01	15.45
15	Fallow		Wheat	21.4	Wheat	26.98	Wheat	21.47	23.28
16	Wheat	20.50	Barley	24.6	Wheat	25.31	Timothy and Clover	2.23 T.	22.90
17	Wheat	*	Barley	14.3	Wheat	28.08	Clover	2.36 T.	28.08
18	Wheat	*	Wheat	16.7	Wheat	30.16	Peas	2.77 T.	23.43
19	Wheat	16.40	Wheat	18.2	Wheat	17.28	Wheat	17.48	17.34
20	Potatoes	*	Wheat	16.8	Wheat	30.57	Wheat	21.65	22.67
21	Wheat	20.10	Wheat	14.2	Spring Rye	24.74	Wheat	23.47	19.25
22	Wheat	16.50	Wheat	11.7	Barley	39.03	Wheat	21.68	16.62
23	Wheat	14.90	Wheat	8.1	Oats	58.18	Wheat	20.69	14.56
24	Wheat	19.50	Wheat	14.5	Wheat	13.57	Wheat	14.19	15.44
25	Wheat	11.45	Wheat	10.3	Wheat	22.84	Wheat	17.74	15.58
26	Fallow		Wheat	16.7	Wheat	25.41	Wheat	21.43	21.18
27	Wheat	*	Wheat	13.8	Timothy	*	Timothy	1.57 T.	13.80
28	Wheat	*	Wheat	16.7	Wheat	30.17	Wheat	22.80	23.22
29	Flax	8.4	Fallow		Wheat	27.99	Wheat	21.49	24.74
30	Flax	12.6	Wheat	22.0	Flax	12.34	Flax	7.37	22.00
31	Flax	10.5	Wheat	20.2	Flax	17.81	Wheat	22.95	21.57
32	Fallow		Flax	16.4	Wheat	33.70	Wheat	22.94	28.32
33	Wheat	19.15	Flax	10.3	Wheat	25.20	Wheat	18.55	20.96
34	Flax	13.4	Wheat	18.8	Wheat	25.85	Wheat	17.35	20.66
35	Corn	*	Wheat	20.8	Flax	18.70	Corn	*	20.80

* No record.

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for the Third Four year Period (Cont.)

1900		1901		1902		1903		Average Yield of Wheat for Period
CROP	YIELD	CROP	YIELD	CROP	YIELD	CROP	YIELD	
1 Wheat	6.20	Brome		Brome		Brome	.595	6.20
2 Wheat	3.95	Wheat	20.09	Wheat	14.70	Wheat	16.38	13.78
3 Timothy	*	Wheat	23.44	Wheat	26.10	Wheat	28.13	25.89
4 Fallow		Wheat	16.99	Wheat	28.30	Wheat	35.47	26.92
5 Corn	35.21	Wheat	20.56	Wheat	25.00	Wheat	23.35	22.97
6 Corn-Man	40.30	Wheat	23.45	Wheat	30.20	Wheat	30.10	27.91
7 Field Peas	*	Wheat	21.00	Wheat	13.70	Wheat	15.05	16.58
8 Field Peas Plowed under		Wheat	22.18	Wheat	23.00	Wheat	21.10	22.09
9 Millet	*	Wheat	22.93	Wheat	21.60	Wheat	21.00	21.84
10 Milllet-Man	*	Wheat	28.63	Wheat	29.60	Wheat	28.97	29.06
11 Millet Plowed under		Wheat	24.56	Wheat	26.20	Wheat	21.33	24.03
12 Rape Green	6.41 T.	Wheat	23.24	Wheat	19.70	Wheat	16.40	19.78
13 Mangels		Wheat	22.50	Wheat	19.30	Wheat	18.00	19.93
14 Fallow		Wheat	20.08	Wheat	18.50	Wheat	10.95	16.51
15 Fallow		Wheat	23.16	Wheat	21.30	Wheat	21.63	22.03
16 Hay		Wheat	25.66	Wheat	26.20	Barley	38.00	25.93
17 Clover		Wheat	14.44	Wheat	22.20	Barley	46.32	18.32
18 Wheat	7.84	Wheat	22.20	Wheat	27.90	Clover	2.47 T.	19.31
19 Fallow		Wheat	18.40	Brome	1.45 T.	Brome	2.44 T.	18.40
20 Potatoes	136.00	Wheat	20.73	Wheat	Not recorded	Wheat	21.58	21.15
21 Wheat	4.25	Corn-Silage	11.2 T.	Flax	18.50	Wheat	27.88	16.06
22 Wheat	3.44	Barley	47.44	Wheat	10.70	Wheat	14.90	9.68
23 Fallow		Flax	9.40	Wheat	29.70	Wheat	26.08	27.86

* No Record

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for the Third Four Year Period (Cont.)

24	Fallow		Wheat	11.13	Wheat	10.70	Clover and Timothy	3.32 T.	10.91
25	Fallow		Brome	*	Brome	1.31 T.	Brome	2.74 T.	
26	Fallow		Wheat	18.66	Wheat	21.90	Wheat	16.62	19.06
27	Wheat	1.55	Hog Millet	*	Wheat	29.90	Wheat	27.45	19.63
28	Timothy	*	Timothy	*	Timothy	2.46 T.	Timothy	3.21 T.	
29	Flax	10.37	Fallow		Wheat	18.40	Wheat	28.15	23.27
30	Flax	*	Path. Invest.		Pathological Invest.		Pathological Invest.		
31	Flax	3.66	Wheat	16.28	Flax	6.26	Pathological Invest.		16.28
32	Fallow		Flax	13.00	Wheat	23.60	Wheat	34.55	29.07
33	Flax	5.33	Wheat	18.75	Wheat	15.00	Flax	10.50	16.92
34	Flax	4.37	Corn-Silage	11.09	Wheat	27.00	Wheat	28.57	27.78
35	Wheat	23.89	Flax	4.32	Corn	*	Wheat	35.75	29.82

* No record.

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for the Fourth period.

	1904		1905		1906		Average Yield of Wheat for Period
	CROP	YIELD	CROP	YIELD	CROP	YIELD	
1	Brome	*	Brome	2.99 T.	Brome	E. 1.96 T. W. 2.75 T.	
2	Wheat	Not recorded	Wheat	Not recorded	Wheat	Not recorded	
3	Wheat	15.00	Timothy	*	Timothy	2.40 T.	15.00
4	Fallow		Wheat	17.85	Wheat	12.50	15.17
5	Corn	30.00	Wheat	20.60	Wheat	12.00	16.30
6	Corn-Man	37.00	Wheat	20.60	Wheat	16.10	18.35
7	Peas	Not recorded	Wheat	15.40	Wheat	6.40	10.90

* No Record.

TABLE III.—Crop Rotation Experiments—Series No. I.—Yields for the Fourth Period (Cont.)

8	Peas Plowed under		Wheat	18.15	Wheat	7.50	12.82
9	Millet	1.25 T.	Wheat	18.20	Wheat	10.90	14.55
10	Millet-Man	2.09 T.	Wheat	24.40	Wheat	13.50	18.95
11	Millet Plowed under		Wheat	23.55	Wheat	8.60	16.07
12	Rape	Not recorded	Wheat	20.00	Wheat	4.70	12.35
13	Mangels	13.40 T.	Wheat	20.80	Wheat	7.70	14.25
14	Fallow		Wheat	17.35	Wheat	4.20	10.77
15	Fallow		Wheat	23.00	Fallow		23.00
16	Wheat	9.30	Timothy and Clover	2.61 T.	Hay	2.50 T.	9.30
17	Wheat	8.70	Clover	2.16 T.	Flax	5.40	8.70
18	Wheat	9.10	Wheat	Not rceorded	Wheat	19.40	14.25
19	Flax	27.60	Wheat	17.95	Wheat	8.00	12.97
20	Potatoes	78.00	Wheat	18.95	Wheat	7.90	13.42
21	Wheat	16.95	Corn	26.70	Flax	7.50	16.95
22	Barley	Not recorded	Fallow		Wheat	22.20	22.20
23	Potatoes	48.50	Flax	10.17	Wheat	15.30	15.30
24	Flax	11.67	Fallow		Wheat	10.80	10.80
25	Wheat	11.40	Wheat	11.00	Wheat	7.70	10.03
26	Fallow		Wheat	16.75	Wheat	7.70	12.22
27	Hog Millet	*	Wheat	21.50	Wheat	15.40	18.45
28	Wheat	11.90	Wheat	24.95	Wheat	22.10	19.65
29	Flax	10.55	Fallow		Wheat	17.05	17.05
30	Pathological Investigations		Pathological Investigations		Pathological Investigations		
31	Pathological Investigations		Pathological Investigations		Pathological Investigations		
32	Fallow		Flax	Not recorded	Wheat	21.10	21.10
33	Wheat	Not recorded	Fallow		Wheat	19.40	19.40
34	Flax	16.10	Flax	Not recorded	Flax	Not recorded	
35	Flax	8.80	Corn	21.38	Wheat	15.70	15.70

* No record.

AVERAGE YIELDS AND VALUE OF PRODUCTS PRODUCED UNDER VARIOUS SYSTEMS OF CROPPING

While there has been some change from the original plan of cropping on some plots in the main it has been carried out as planned and a study of the average yield of wheat on the plots will indicate the relative merits of the various systems for wheat production. It is not only of interest to know the average yield of wheat for the years in which it was seeded but it is also of some importance to know the relation between the total bushels of wheat produced in the respective cropping systems. Table IV is a summary of the yields on the plots in Rotation Series No. 1 and the value per acre of the products. The prices of wheat, corn, oats, barley, rye, potatoes, hay and flax on which these values are based, are taken from the year books of the U.-S. Department of Agriculture for the year in which the respective crops are produced. The farm price Dec. 1st is used except in the case of flax where the Duluth price was taken. Corn fodder is valued at 75 per cent of the value of hay for the year in which it was produced. Green corn cut for silage, mangels and rape were estimated at 25 per cent of the value of hay in the years in which they were produced. Millet and peas cut for hay were given the same value as hay and threshed peas were valued at $2.50 per bushel.

TABLE IV.—Summary of Results on Rotation Series No. I.

Plot No.	Cropping	Total bushels of wheat per acre	Value of wheat per acre	Value of all crops per acre	Av'ge annual yield of wheat per acre	Average of recorded yields of wheat
1	Wheat continuously until 1900; brome grass since	158.68	$ 81.30	$118.20	17.63	17.63
2	Wheat continuously since 1882	206.04	109.39	109.39	13.73	17.17
3	4 years wheat; 2 years timothy	181.06	104.77	113.28	12.07	22.63
4	3 years wheat; 1 year fallow	245.71	141.00	141.00	16.38	22.33
5	3 years wheat; 1 year corn	233.81	127.48	170.30	15.58	21.26
6	3 years wheat; 1 year corn-manured	262.71	146.28	196.09	17.51	23.88
7	3 years wheat; 1 year field peas	197.81	106.47	168.35	13.18	18.89
8	3 years wheat; 1 year field peas—plowed under	207.77	112.34	112.34	13.85	18.88
9	3 years wheat; 1 year millet	225.16	122.22	140.44	15.01	20.46
10	3 years wheat; 1 year millet—manured	266.43	147.32	169.01	16.68	22.74
11	3 years wheat; 1 year millet—plowed under	230.17	125.69	125.69	15.34	20.92
12	3 years wheat; 1 year rape	222.23	119.37	151.28	14.81	20.20
13	3 years wheat; 1 year mangels	220.37	119.83	128.89	14.62	20.03
14	Wheat continously until 1900	204.85	112.42	112.42	13.65	15.61
15	3 years wheat; 1 year fallow	225.19	122.17	122.17	15.01	22.51
16	1 yr. wheat; 2 yrs. hay; 2 yrs. wheat; 1 yr. barley	146.20	85.60	131.30	9.75	18.27
17	1 yr. wheat; 2 yrs. clover; 2 yrs. wheat; 1 yr. barley	157.57	84.58	142.09	10.50	22.51
18	3 yrs. wheat; 1 yr. peas; 1 yr. wheat; 2 yrs. clover	113.68	62.12	109.28	7.58	18.94
19	Wheat contin. until 1900; clover seeded in wheat	192.63	103.55	151.65	12.84	18.42
20	3 years wheat; 1 year potatoes	208.40	109.84	176.48	13.89	20.84
21	2 years wheat; 1 year spring rye	135.95	81.60	157.85	9.06	16.99
22	2 years wheat; 1 year barley	126.02	72.07	114.54	8.40	14.00
23	2 years wheat; 1 year oats	142.82	81.43	167.26	9.52	17.85
24	Wheat continuously until 1900	164.22	86.99	115.60	10.94	15.83
25	Wheat continuously until 1900	157.73	85.80	104.22	11.11	15.15

TABLE IV. (Cont.)—Summary of Results on Rotation Series No. I.

26	Wheat 3 years; fallow 1 year	205.47	110.58	110.58	13.69	18.67
27	Wheat 3 years; timothy 2 years	153.90	89.53	103.50	10.26	19.26
28	Wheat 4 years; timothy 3 years	142.46	83.64	137.29	9.49	20.35
29	Wheat 2 years; flax 1 year; fallow 1 year	152.58	80.10	115.94	10.17	21.99
30	Flax continuously 1893—1901	50.00	30.07	83.44	5.55	16.60
31	Wheat 1 year; flax 1 year 1894—1903	99.73	53.65	105.13	9.06	16.62
32	Wheat 2 yrs; fallow 1 yr. flax 1 yr.; 1895—1906	166.99	90.16	132.12	11.13	23.85
33	Wheat 2 years; flax 1 year 1894—1903	156.45	83.41	126.01	8.15	15.29
34	Flax 1 yr.; corn 1 yr.; 2 yrs. wheat 1894—1906	193.69	105.55	156.40	12.91	21.52
35	Wheat 1 yr.; flax 1 yr.; corn 1 yr. 1894—1904	105.77	62.66	107.82	7.05	26.44

WHEAT PRODUCED UNDER VARIOUS CROPPING SYSTEMS.

The greater part of the income on practically all plots was from wheat. From the standpoint of wheat alone, plot 10 ranks first, the cropping being wheat three years and millet manured one year. In case the soil is new and the production of wheat is the only end in view this would be the best rotation in this series. Of course such a rotation would not be possible on most farms as there is no grain produced for feed and in order to produce six tons of rotted manure per acre once in four years it would be necessary to feed some live stock.

Ranking second in amount and value of wheat produced is plot 6 which grew wheat three years and corn manured one year. It is significant that the only plots in the rotation that were manured produced the most wheat. The total value of all crops produced was greater on plot 6 than on plot 10 and as some feed grain is produced in this system it would prove to be more practicable than that on plot 10. It would hardly be possible to produce six loads of rotted manure per acre even under this system, but more would be produced than would be possible with millet in rotation with wheat as on plot 10. The plot ranking third in wheat produced was plot 4 on which the land was fallowed every fourth year wheat being grown the other three years. There were eleven plots that ranked higher in the total wheat produced than plot 2 on which wheat has been seeded every year since the experiment was started. Hence it is evident that there are several systems by which more wheat can be produced than by growing wheat every year. It is significant, however, that the only systems under which more wheat was produced than by continuous cropping were those in which there was a cultivated crop or a short season forage crop. This is no doubt accounted for in part by the fact that the land was in wheat for a greater proportion of the time when these particular rotations were followed but it is due in part to incompleteness of the records on account of weediness and crop failure on plots where other systems were practiced. In the timothy and clover rotations a good stand of these crops was not always obtained and in some seasons wheat seeded on land that had been in sod the previous year failed to produce a satisfactory crop. It is evident from the results obtained that while a hay crop is quite essential in a rotation, if the maximum yields are to be obtained there must also be a cultivated crop to keep the soil in good physical condition and conserve the moisture for possible dry seasons.

According to the original plan, clover was to be grown two years in succession in the rotation outlined for plots 17 and 18. It will be noted that in no case was there a crop of clover the second year. As clover is recognized as a biennial this is what would be expected for the clover is seeded with a nurse crop the year before it appears in the rotation.

The short season forage crops like rape and millet are seeded late in the season and some cultivation is required to keep down weeds until seeding time. In addition to the killing of a large number of weeds, this improves the physical condition of the soil. These crops grow very rapidly and there is little chance for the weeds which grow with the small grains to mature seed.

TOTAL VALUE OF ALL CROPS PRODUCED.

Of the plots which failed to produce as much wheat as the continuous wheat plot there were only five which failed to produce crops of greater total value. The cropping system which showed the lowest total crop value was in flax continuously from 1893 to 1901. As it was discontinued as a rotation plot at the latter date only nine crops of any kind were harvested from it. The next lowest value produced by any plot was that on plot 27. The failure to secure a stand of timothy and interruption of the original system are largely accountable.

When flax and wheat were seeded in alternate years on plot 31 the income was smaller than when wheat was grown continuously.

Even when corn was grown one year, wheat one year followed by flax one year on plot 35 the total value of products was less than when wheat was grown continuously.

However, when wheat is grown two years after corn and then a crop of flax grown as on plot 34 a fair income is secured.

On account of the failure of clover the second year of the rotation the total value of the products on plot 17 was practically the same as when wheat was grown continuously.

If a cultivated crop had been put in the place of the second year of clover the writers have no doubt this would have been one of the most profitable systems.

The three plots on which a rotation consisting of small grains only was practised failed to produce as much wheat as the continuous wheat plot but they all produced a greater total crop value. The rotation consisting of oats, one year, wheat, two years produced the greatest value of these three and when spring rye took the place of oats the total crop value was greater than when barley occupied this place in the cropping system.

AVERAGE YIELDS UNDER VARIOUS SYSTEMS.

In the fourth column of table IV are given the average yields for the fifteen year period. In one or two cases where the cropping has been materially changed it is the average for a shorter period. Such is the case with plots 1, 30 and 31. It will be noted that the highest average yield was on plot 1 but as this plot grew wheat for the first nine years only it is not fair to assume that it would have had the highest average if it had been conducted as a continuous wheat plot until 1906. It grew wheat during the early part of the period when the soil was in fairly good condition and it will be noticed that all yields are higher during the time plot 1 was conducted as a continuous wheat plot than in succeeding years. There was a marked falling off on plot 2 after plot 1 was discontinued as a continuous wheat plot. The differences in yields are largely due to the arrangement of crops in the rotation and the proportionate time of the period the land is in wheat, although there are some striking variations in the yields on rotation of similar length and arrangement.

The average of recorded yields in column 5 of table IV show some striking differences. The highest average yield per acre was produced in the rotation of corn manured one year; wheat, three years. This is the average of eleven crops. Various contingencies prevented the recording of yields in some years on some plots but for the most part these are the averages for the years in which the land was seeded to wheat.

ROTATION VERSUS CONTINUOUS CROPPING.

While there is great variation in the yields of all the plots from year to year there has been a marked difference in the yield of plots that were cropped to wheat continuously and those on which wheat was grown in rotation with other crops. In table V the comparison between the two is shown

It will be noted that there was little difference the first year, but later there was a marked increase. In every year except 1895 those plots on which a rotation was followed yielded considerably more than those cropped continuously. The average increase was 5.99 bushels per acre.

TABLE V.—Average Yields of Wheat on Plots Cropped Continuously and those in Rotation. Rotation Series No. I.

Year	Average Yield per acre of all plots cropped to wheat continuously	Average Yield per acre of all plots which were in a rotation system	Increase due to Rotation
1892	19.76	17.80	-1.90
1893	9.36	14.03	4.67
1894	19.74	22.78	3.04
1895	23.41	23.10	-.30
1896	16.20	18.23	2.03
1897	14.75	18.12	3.37
1898	20.05	28.50	8.45
1899	17.44	21.05	3.61
1900	5.07	8.19	3.12
1901	20.09	21.54	1.45
1902	14.70	23.62	8.92
1903	16.38	24.63	8.25
1904	No yield recorded	11.82	11.82
1905	No yield recorded	20.31	20.31
1906	No yield recorded	13.02	13.02
Av'ge	13.13	19.12	5.99

The yields given for the continuous wheat were the average of several plots until 1900. At that time several of the plots that had been cropped to wheat continuously were discontinued as such. After that time plot No. 2 was the only plot that was retained to be so cropped hence the data from 1901 to 1906 is for one plot only. Some wheat grew on the plot in 1904, 1905 and 1906 but it was so weedy that it was not considered worth cutting. It may seem that the increase is a little large for those three years but it is accordance with what would have been done in actual farm practice, because the best cultural methods that would be followed in a system of continuous single cropping were used.

It might be noted that plot No. 2 has not reached the point where it will not produce wheat any longer for yields have been secured for 1909, 1910 and 1911. While these are not high they show the land can still produce wheat. It is to be retained as a continuous wheat plot indefinitely.

RELATION OF WEATHER CONDITION TO YIELD.

It will be noted that there is much variation in yield from year to year. These variations are largely due to the variation in weather conditions. In some years the rainfall is insufficient to keep the supply of soil water high enough to meet the demands of the crop during the growing season.

The rainfall record is the most authentic source of information we have at hand from which to determine the relation between the soil water supply and crop yield but the storage of water which may have fallen as rain some time previous makes this relation rather uncertain. This is especially true of a clay soil high in organic matter.

In some years such a large amount of rain has fallen during the growing season that the crop yield is decreased because of an excess of water in the soil. Other seasons there have been periods of hot moist weather at the time of the year when the wheat rust can take advantage of it and develop rapidly thereby lessening the yield materially. Heavy rains at harvest time have caused a reduction of yield in some cases. The conditions favorable to weed growth have been better in some years than in others and when conditions are favorable for weed growth the yield of wheat is usually correspondingly reduced.

Table VI compiled from the records of the Station shows the monthly rainfall for the period during which these experiments have been in progress. For convenience the total rainfall during the months of April, May, June and July is tabulated in addition to the annual rainfall.

TABLE VI.—Monthly Precipitation Record 1892—1910.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Rainfall Apr., May, June and July
1892	.04	.27	1.07	2.42	3.88	1.93	5.02	4.03	1.39	.36	.50	.12	21.03	13.25
1893	.22	.11	.71	2.63	.77	3.62	2.20	2.72	.87	.90	1.00	.41	16.16	9.22
1894	.09	.09	1.29	3.35	2.62	6.23	.80	1.17	.56	2.11	.29	.12	18.72	13.00
1895	.36	.13	.00	1.36	1.62	4.81	3.24	1.60	.00	1.00	1.16	.01	14.29	14.03
1896	.19	.06	.48	3.64	4.70	2.71	.91	2.17	2.58	1.96	.70	.26	20.36	11.96
1897	.36	.77	.96	.89	.74	7.10	8.24	.77	.57	1.81	.25	.04	22.50	16.97
1898	.06	.10	.34	.88	3.99	2.25	2.59	2.84	1.23	1.62	.08	.22	16.20	9.71
1899	.29	.29	1.58	1.39	4.22	3.44	2.78	3.71	1.24	1.67	.27	.33	21.21	11.83
1900	.45	.54	1.23	1.82	.81	2.11	3.91	8.28	3.27	2.80	.20	.12	25.54	8.65
1901	.05	.11	1.31	1.76	.98	5.91	7.29	1.59	2.57	3.83	.00	.28	23.16	15.94
1902	.34	.34	1.42	2.30	4.25	3.07	2.54	2.95	.58	5.17	.19	.17	23.81	12.16
1903	.83	.45	.42	1.34	2.78	.56	2.62	4.61	5.61	2.49	.10	1.00	20.26	7.30
1904	.13	.45	.95	2.74	1.47	3.83	2.83	.69	3.49	2.30	.01	1.37	30.76	10.87
1905	.80	Trace	.51	1.28	5.77	5.00	5.17	6.82	3.47	1.18	.71	.05	17.70	12.22
1906	.62	.24	.38	2.28	3.03	3.11	2.68	2.22	1.18	.75	1.01	.27	15.34	11.10
1907	.34	.08	.10	.08	1.37	3.12	2.39	2.84	3.90	.84	.13	.15	18.98	6.96
1908	.01	.03	.52	.58	3.02	2.60	2.78	2.55	2.54	.74	2.39	.22	18.98	8.98
1909	.01	.25	.29	.61	4.15	2.73	2.76	3.52	1.45	1.29	1.11	1.47	19.64	10.25
1910	.52*	.52*	.36*	1.01	.88	.83	.85	.91	1.60	.59	.51	.19	8.77	3.57
Av'ge	.30	.25	.73	1.70	2.68	3.42	3.24	2.94	2.00	1.75	.55	.35	19.63	10.94

*From records of U. S. Weather Bureau at Moorhead, Minn., which is only about two miles distant from this Experiment Station and the precipitation would be practically the same.

Chart 1 shows the relation of the rainfall to crop yield. The yield does not follow the rainfall very closely because in some years the rainfall is evidently too high for maximum production and in other years it is too low. The period is too short, however, to draw any definite conclusions. In some years excessive rainfall during one month may account for low yields and in another year a deficiency in the rainfall may have like results. In other years these conditions in other months may have similar effects.

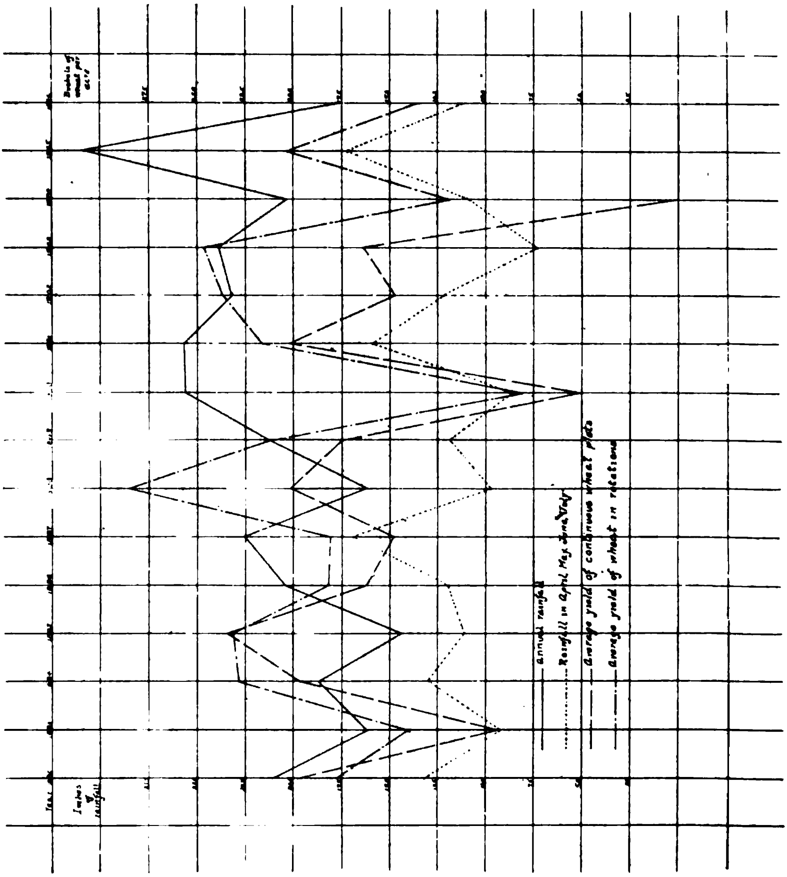

Chart I. The relation of rainfall to wheat yield.

ROTATION AND WEEDS.

All plots on which wheat was grown continuously and those on which a rotation containing only small grains was practiced were the first to become weedy. The yield on these plots had been materially decreased on this account and finally they became so weedy that they were discontinued. Plat No. 2. was retained, however, and every possible means of eradication that can be practiced in continuous wheat cropping was used. Weeds which have the same period of growth as small grains produce seeds and increase in number each year. This makes the conditions unfavorable to wheat growing on such land cumulative. The principal difficulty in carrying out the original plan of cropping on plots 1, 2, 14, 19, 21, 22, 23 24 and 25 was the accumulation of weeds. When barley has been placed in a rotation with wheat some of the weeds have been kept down as the barley has a somewhat shorter growing season than the other small grain crops. If the land can be plowed immediately after the crop has been removed and the land kept clean of weeds during the remainder of the season this rotation can be made quite effective in combating weeds.

Ordinarily, spring rye and oats do not ripen in time to permit the removal of the crop early enough to permit plowing before the rush of the wheat harvest. Owing to the similarity of the growing season of wheat and oats, and wheat and spring rye the introduction of these crops into the rotation does not help materially in fighting weeds which are a menace to wheat growing. On plot 21 a rotation of spring rye one year; wheat two years was followed. This was continued until 1901 when it was put in corn so that cultivation might be given to clean the weeds out. On plot 23 the original rotation was oats one year; wheat two years. The weed problem was as bad or worse than on plot 21 so that the rotation was discontinued and the plot was fallowed in 1900.

In order to obtain a measure of the effciency of the various cropping systems in combatting weeds a count of the wild oats present was made in 1898 and 1899. The results of these counts are shown in Table VII.

TABLE VII.—The Influence of the Cropping System on the accumulation of Wild Oats.

Plot No.	Cropping System	Wild Oats Present	
		1898	1899
1	Wheat continuously	.25%	1.00%
2	Wheat continuously	.50	5.00
3	4 yrs. wheat, 2 yrs. timothy	0.00	0.00
4	3 yrs. wheat, 1 yr. fallow	.25	2.00
5	3 yrs. wheat, 1 yr. corn	.01	0.00
6	3 yrs. wheat, 1 yr. corn (manured)	T	0.00
7	3 yrs. wheat, 1 yr. field peas	4.00	T
8	3 yrs. wheat, 1 yr. field peas (plowed under)	3.00	3.00
9	3 yrs. wheat, 1 yr. millet	T	1.00
10	3 yrs. wheat, 1 yr. millet (man.)	0.00	0.00
11	3 yrs. wheat, 1 yr. millet (plowed under)	T	5.00
12	3 yrs. wheat, 1 yr. rape	.25	7.00
13	3 yrs. wheat, 1 yr. mangels	.01	2.00
14	Wheat continuously	40.00	30.00
15	3 yrs. wheat, 1 yr. fallow	T	1.00
16	1 yr. wheat, 2 yrs. hay, 2 yrs. wheat, 1 yr. barley	T	0.00
17	1 yr. wheat, 2 yrs. clover, 2 yrs. wheat, 1 yr. barley	0.00	0.00
18	3 yrs. wheat, 1 yr. peas, 1 yr wheat, 2 yrs. clover	1.00	0.00
19	Wheat continuously	30.00	15.00
20	3 yrs. wheat, 1 yr. potatoes	T	1.00
21	2 yrs. wheat, 1 yr. spring rye	5.00	T
22	2 yrs. wheat, 1 yr. barley	10.00	T
23	2 yrs. wheat, 1 yr. oats	10.00	15.00
24	Wheat continously	50.00	70.00
25	Wheat continuously	5.00	30.00
26	Wheat 3 yrs., fallow 1 yr.	10.00	8.00
27	Wheat 3 yrs., timothy 2 yrs.	0.00	0.00
28	Wheat 4 yrs., timothy 3 yrs.	T	1.00
29	Wheat 2 yrs., flax 1 yr., fallow 1 yr.	0.00	T
30	Flax continuously (1893-1901)	15.00	0.00
31	Wheat 1 yr., flax 1 yr. (1894-1903)	2.00	0.00
32	Wheat 2 yrs., fallow 1 yr., flax 1 yr, (1895-1906)	0.00	0.00
33	Wheat 2 yrs., flax 1 yr., (1894-1903)	0.00	5.00
34	Flax 1 yr., corn 1 yr., wheat 2 yr. (1894-1906)	0.00	2.00
35	Wheat 1 yr., flax 1 yr., corn 1 yr. (1895-1904)	2.00	0.00
Average of continuous wheat plots		20.96	25.16
Average of plots in rotation		1.69	1.96

It will be noted from the above table that the wild oats had accumulated most rapidly on the continuous wheat plots. While the percentage is not so high on the plots on which a system of small grains only was followed, it is much higher on these plots than when the cropping system contained a cultivated crop or a short season forage crop.

Field peas in rotation with wheat failed to keep down the wild oats as effectively as some of the later sown crops. This is probably due in part to the fact that the growing season of the field pea is quite similar to wheat.

THE INFLUENCE OF INDIVIDUAL CROPS ON SUCCEEDING WHEAT YIELDS.

While many of the cropping systems herein outlined would not work out satisfactorily in farm practice the data obtained in these experiments throw a great deal of light on the influence of various crops on succeeding wheat yields. In many cases all other factors except the introdution of one single crop into a rotation with wheat have been eliminated, thus affording very definite data with reference to the influence of this particular crop on succeeding wheat yields. Each of the crops studied will be taken up separately.

THE INFLUENCE OF CORN IN ROTATION WITH WHEAT.

It is quite generally recognized that the cultivation given the corn crop improves the physical, chemical and biological relations of the soil so that it is in better condition for wheat production. In order to get at the benefits measured by crop yield plots 5 and 6 were cropped to corn one year followed by three years of wheat. Plot 6 received an application of six loads of rotten manure per acre. No application was made to plot 5. In Table VIII the yields for these two plots are summarized and compared with the yields on plot 2 which has been in wheat continuously during the period. The yields for the first year and second year after corn are the average of four crops and the yields the third year after corn are the average of three crops.

TABLE VIII.—The Influence of Corn on Succeeding Wheat Yields.

Plot	Wheat After	1st yr. after		2nd yr. after		3rd yr. after	
		Yield	Increase	Yield	Increase	Yield	Increase
2	wheat	11.27		15.39		19.40	
5	corn	19.14	7.87	22.96	7.57	21.80	2.40
6	corn	20.48	9.11	25.85	10.46	25.78	6.38

The highest yields were obtained the second year after corn. This group of years was somewhat more favorable for wheat production than either of the other two but the yields on the continuous wheat plot indicate that the first group of years was by far the most unfavorable. The real test of the influence of the corn, however, is measured by the increase in yield over continuous wheat. The significant facts brought out by the above data are as follows:—

1. The culture of corn increased succeeding wheat yields.

2. The benefit of the corn crop is greatest in the two years immediately succeeding the year in which it is grown.

3. An application of farm manure once in four years increases the yields of wheat in a rotation with corn.

In these experiments the increase due to farm manure was 1.24 bushels the first year after the manuring, 2.89 bushels the second year after, 3.90 bushels the third year. The total increase was 8.11 bushels or 11.2 per cent. Each load of manure produced 1.35 bushels of wheat.

4. The beneficial effects of such manuring extended over a longer period than the effects of corn in the rotation.

THE INFLUENCE OF POTATOES IN ROTATION WITH WHEAT.

The culture given potatoes is quite similar to that given corn and as potatoes can be marketed directly to better advantage than corn in this locality, providing there is a shipping point close at hand, some farmers prefer to raise potatoes as a cultivated crop. In order to determine the effect of potato culture on succeeding wheat yields a rotation consisting of potatoes one year and wheat three years was started on plot 20 in 1896. As plot 19 was originally planned to be seeded to wheat continuously and was continued as such until 1900 comparisons can be made between these two plots for one four year period.

TABLE IX.—The Influence of Potatoes on Succeeding Wheat Yields.

Plot	Wheat After	First Year	Second Year	Third Year
19	wheat	18.30	17.28	17.48
20	potatoes	16.80	30.57	21.65
Increase		−1.40*	13.29	4.17

*Decrease

While the period during which this work was conducted was too short to draw any definite conclusions it is evident that the introduction of potatoes into the rotation has a marked beneficial effect on wheat yields. As was the case with corn, the beneficial effects were not as marked the third year after potatoes were grown as the second year but there was no increase over continuous wheat the first year after the potato crop was produced. It will be noted from Table III, however, that plot 19 was discontinued as a continuous wheat plot in 1900 on account of extreme weediness while plot 20 produced fairly good yields until the plan of the experiment was changed in 1906. Furthemore, plot 2, which has been maintained as a continuous wheat plot, failed to produce satisfactory yields in these latter years.

THE INFLUENCE OF MANGELS IN ROTATION WITH WHEAT.

In systems of live stock farming root crops sometimes furnish the succulent feed. To obtain the best results they require intensive tillage. In some European countries roots are the principal cleaning crop in a rotation. Mangels usually give larger yields than most other root crops and in order to determine the effect of the culture given such crops a rotation consisting of mangels one year and wheat three years was started on plot 13 in 1892. As plot 14 was cropped continuously with wheat until 1900 we have two four year periods which furnish data from which the effect of mangels on wheat yields can be calculated.

TABLE X.—The Influence of Mangels on Wheat Yields in a Four Year Rotation.

Plot	Wheat After	First Year	Second Year	Third Year
13	mangels	19.80	25.88	20.35
14	wheat	12.85	17.31	18.25
Increase		6.95	8.57	2.10

The increase in wheat yield due to the mangel culture is similar to that produced by corn. There is a marked increase the first and second years after mangels have been grown while the increase the third year is only 2.1 bushels per acre. While the data is somewhat limited it is evident on farms carrying live stock enough to dispose of the mangel crop it would prove to be a valuable crop in rotation with wheat.

THE INFLUENCE OF RAPE IN ROTATION WITH WHEAT.

The short season forage crops grow rapidly and as they are seeded late many weeds are killed in the preparation of the soil for the crop. Furthermore, the late tillage promotes ammonification and nitrification by furnishing better aeration during the warmer months. These crops are usually seeded after the heavy spring rains and the soil is less compact than in small grain fields during the remainder of the summer.

Rape is a rank growing crop commonly used for sheep pasture. In order to determine its effect on succeeding wheat yields a rotation consisting of rape one year and wheat three years was started on plot 12 in 1892. In order to determine the influence of rape the yields on this plot are compared with plot 14, the nearest continuous wheat plot, in Table XI.

TABLE XI.—The Influence of Rape on Succeeding Wheat Yields.

Plot	Wheat After	First Year	Second Year	Third Year
12	Rape	20.40	26.15	22.54
14	wheat	12.85	17.31	18.25
Increase		7.55	8.84	3.29

The effect of rape on wheat yields is similar to that of mangels except that the increase is slightly greater. The difference between the increases on the two plots is only 2.6 bushels, however. The beneficial effects of the rape are much less marked the third year after it has been grown than they are in the first and second years. The rape crop was not grazed off in this trial hence the benefit from manure of pasturing animals, natural in such cropping was eliminated.

THE INFLUENCE OF FIELD PEAS IN ROTATION WITH WHEAT

It is often desirable and sometimes necessary to replace a biennial or perennial legume with an annual legume. The latter fit into short rotations a little better and as a rule it is comparatively easy to secure a stand. If for any reason a stand of clover is not obtained the provious year the land must be seeded to an annual legume if the rotation is to be maintained without interruption. For the Northwest field peas have proved to be the most satisfactory annual legume crop. In order to determine the influence of field peas on wheat yields a rotation consisting of peas one year and wheat three years was carried out on plots 7 and 8. The pea crop was removed from plot 7 and plowed under on plot 8. Table XII shows a comparison of the yields of these plots with those on plot 2, the continuous wheat plot for the same years.

TABLE XII.—The Influence of Field Peas on Succeeding Wheat Crops.

Plot	Wheat After	First Year		Second Year		Third Year	
		Yield	Increase	Yield	Increase	Yield	Increase
2	wheat	11.27		15.39		19.37	
7	peas	17.80	6.53	17.32	1.93	10.08	-.29
8	peas	15.91	4.64	19.49	4.10	21.73	2.36

The turning under of the pea crop failed to produce an increase in wheat yield the first year after but there was a gain of 2.17 bushels the second year and 2.65 bushels the third year attributable to the green manuring. A study of this data in connection with the detailed yields in table III indicate that green manuring with field peas does not give immediate results in a soil well supplied with organic matter but when such manuring is practised regularly the beneficial results are cumulative. In the last half of the period the yield on the green manured plot was greater than that from which the peas were removed. The plot from which the peas were removed showed an increase in yield over the continuous wheat plot the first and second years but the beneficial effects did not extend to the third crop of wheat following. It will be noted from Table III, however, that yields were obtained from plots 7 and 8 in 1905 and 1906 when wheat was a failure on plot 2.

THE INFLUENCE OF MILLET ON SUCCEEDING WHEAT YIELDS.

It has been noticed by many farmers in the state that wheat seeded on land that has grown a crop of millet the preceding year yields better than when seeded on land that has grown small grains only. In order to get a measure of the influence of millet on succeeding wheat yields a rotation consisting of millet one year and wheat three years was established on plots 9, 10 and 11 in 1892. The millet was cut for hay on plot 9. The land was manured for millet on plot 10 and the millet crop was plowed under as green manure on plot 11. Plot 14 is the nearest continuous wheat plot but inasmuch as it was discontinued in 1900 and plot 2 has been seeded to wheat every year the latter is used in calculating the increase due to the millet in the rotation. Plot 2 is quite similar to plots 9, 10 and 11. If there is any difference plot 2 is a little better drained and as an average better suited to crop growth, hence the influence of the millet crop will be reduced rather than exaggerated by using it as a basis for calculating the increase. The average of the first, second and third crops of wheat after millet during the 15 year period on the three plots are compared with the yields of plot 2 for the same years in Table XIII.

TABLE XIII.—The Influence of Millet on Succeeding Wheat Yields.

Plot	Wheat After	First Year		Second Year		Third Year	
		Yield	Increase	Yield	Increase	Yield	Increase
2	wheat	11.27		15.39		19.37	
9	millet	18.68	7.41	21.38	5.99	21.63	2.26
10	millet	22.75	11.48	24.43	9.04	25.15	5.78
11	millet	19.80	8.53	21.64	6.25	21.47	2.10

The influence of the millet was greatest on the first succeeding wheat crop and decreased gradually thereafter. The effects are similar to that of the cultivated crop except that the beneficil effects are more apparent in the first crop of wheat following. The green manuring with millet had much the same effect as the green manuring with peas although the results are somewhat irregular as will be noted from Table III. It is evident from the data in the late years that while millet produced a marked beneficial effect on new land cultivated crops will give better results on land that has been cropped for sometime. This is partly due to the acumulation of pigieon grass (Chætochloa Glauca) which has a growing season similar to the millet plant.

The principal facts brought out by these plots are:—

1. That millet brings about an improvement in soil condition for wheat production.

2. That the application of manure to millet causes a marked increase in yield of succeeding wheat crops. Manure has produced an increase of 4.07 bushels the first year after millet; 3.05 bushels the second year and 3.52 bushels

the third year. Each load of manure has produced 1.75 bushels of wheat.

3. That green manuring with millet produces only a slight increase in the yield of succeeding wheat crops on rich soils.

THE INFLUENCE OF SUMMER FALLOW ON SUCCEEDING WHEAT YIELDS

One of the greatest impediments to the continous production of wheat on the same land is the rapid increase of certain weeds due to the carrying over of the seed from one year to another. In the past summer fallow has been one of the most common methods of cleaning the land of weeds in this state. In order to determine the influence of fallow on succeeding wheat crops plots 4, 15 and 26 were fallowed every fourth year and seeded to wheat the three remaining years. This system was continued an all three plots until 1906 with the exception of one year on one plot. In 1906 plot 15 was fallowed but it should have been in wheat. Inasmuch as plot 2 was the only continuous wheat plot maintained until 1906 no other is used in making comparisons. Plot 4 is separated from plot 2 by only one plot and hence the yields are strictly comparable. The other plots can be compared with plot 4, the principal differences being due to the soil and drainage conditions. A comparison of the yield of the first, second and third wheat crops after fallow with continuous wheat is given in Table XIV.

TABLE XIV.—The Influence of Fallow on Succeeding Wheat Yields.

Plot	Wheat After	First Year		Second Year		Third Year	
		Yield	Increase	Yield	Increase	Yield	Increase
2	wheat	11.27		15.39		19.37	
4	fallow	16.93	5.66	22.26	6.87	27.30	7.93
15	fallow	20.89	9.62	18.51	3.12	22.53	3.16
26	fallow	16.55	5.28	19.00	3.61	21.08	1.61

Plots 4 and 26 were plowed twice and plot 15 was plowed but once, in July. The extra plowing in the fall failed to produce an increase in the yield of the following wheat crops, as indicated by the difference between plots 15 and 26. The yields of plot 4 are not strictly comparable on this point because the fallow was manured with six loads of rotten manure on this plot. The same general tendency of the yields to be maintained after fallow for a longer period when manured as was noted when corn was manured in the rotation is evidenced in this data. The figures indicate that fallow produces a marked increase in yield the first and second years and to a lesser degree in the third year after having been fallowed. It is usually considered, however, to be more economical to have corn take the place of fallow on account of the income received from the corn crop.

THE INFLUENCE OF OTHER SMALL GRAINS ON SUCCEEDING WHEAT YIELDS.

Oats, barley and sometimes spring rye are grown in rotation with wheat and in order to get a measure of their effect on wheat yields plots 21, 22 and 23 were set aside for this purpose. On plot 21 the cropping system was spring rye one year; wheat two years. On plot 22 it was barley one year; wheat two years and on plot 23 it was oats one year and wheat two years. The weeds multiplied so rapidly that the original cropping plan was discontinued in 1900 on plots 21 and 23 and in 1904 on plot 22. Barley seemed to keep the weeds in check better than either of the other crops. Plot 24 was continued as a continuous wheat plot nutil 1900 and so it furnishes a basis of comparison for calculating the effects of the other small grains on succeeding wheat yields. This comparison is shown in Table XV.

TABLE XV.—The Influence of other Small Grains. On succeeding Wheat yields.

Plot	Wheat After	First Year		Second Year	
		Yield	Increase	Yield	Increase
24	Wheat	14.09		16.41	
21	Sp. Rye	18.06	3.97	16.35	–0.06*
22	Barley	14.86	.77	15.10	–1.31*
23	Oats	15.23	1.14	13.05	–3.36*

The yields given for the first year after each crop are the average of three wheat crops, namely, 1893, 1896 and 1899 and those for the second year after are the average of two wheat crops, 1894 and 1897. It will be noted that while there is some small benefit derived the first year after spring rye, barley and oats, it is practically offset by the decrease in yield the following year. It is brought out quite forcibly by the above data that simply changing small grain crops has very little beneficial effect. In fact the yields of wheat after both oats and barley, our most common small grains, are less than on land that has produced wheat continuously since breaking.

THE INFLUENCE OF FLAX ON SUCCEEDING WHEAT YIELDS.

Flax and wheat have both been important money crops in this state. Flax is often seeded on fresh breaking which is seeded to wheat the following year. When the rainfall has been sufficient some very good returns have been secured in this way. Even on the older lands of the Red River Valley some very successful wheat crops after flax have been grown when a complete rotation has been previously practised on the land. In order to get at the benefits of flax on succeeding wheat yields eliminating all other factors in 1894 an alternate system of cropping with flax one year and wheat one year was established on plot 31. This plan was continued until 1903 when it was set aside for pathological work. Four crops of wheat were harvested in this system. The average yield of these four crops was 18.23 bushels per acre while the yield of wheat on plot 2, which lies just across the end alley and of which plot 31 was a part until 1893, was 19.43 bushels for the same years.

The data obtained on plot 33 which was seeded to flax one year followed by two years of wheat, from 1894 to 1903, throws some additional light on this subject. Three crops of wheat the first years after flax and three the second year have been harvested from this plot. Plot 2 is the nearest wheat plot with which it can be compared to get a measure of the effects of the flax crops. The average of the yields obtained are given in Table XVI.

TABLE XVI.—The Influence of Flax on the Yield of Succeeding Wheat Crops.

Plot	Wheat After	First Year	Second Yr.
2	wheat	22.74	17.14
33	flax	22.35	17.51
	Increase	-.39*	.37

*Decrease

The data on plots 31 and 33 indicate that flax and its culture produced practically no changes in the soil which are beneficial to wheat production. The fact that some very good yields of wheat have been obtained on land that has produced flax the preceding year must be accounted for by the soil and crop management preceeding the flax crop. For example, six acres of land on the Experiment Station grounds that had produced flax the preceding year yielded 27.5 bushels of wheat per acre in 1910. The yield on plot 2 of that year was 15.7 bushels per acre. However this field had grown a crop of corn and a crop of clover once in 5 or 6 years for the past 15 years and the good yield must be attributed to these crops rather than to the flax crop.

THE INFLUENCE OF TIMOTHY ON SUCCEEDING WHEAT CROPS.

The beneficial effects of timothy as evidenced by the yields of succeeding small grain crops have been noted by most farmers who have grown the crop. In order to get a measure of this beneficial effect the cropping systems indicated below were established in 1893.

Plot 3, timothy two years; wheat four years; plot 27, timothy two years; wheat three years; plot 28, timothy three years; wheat four years. The records on these plots are fairly complete with the exception of 1896. In 1895 the soil drifted on to these plots so much that the yields for 1896 have been discarded. For this reason no comparison with the wheat yields of the continuous wheat plot for 1896 have been made, hence on plot 3 the yield the second year after timothy is for one year only (1902) while the other yields for this plot are the average of two wheat crops. Plot 25 was the nearest continuous wheat plot with which a fair comparison could be made to determine the effects of timothy on plots 27 and 28 and as it was fallowed in 1900 comparisons of the yields will be limited to the ones from 1893 to 1900. This affords us yields for one course of the rotation only and as the yields for 1896 are eliminated the data is somewhat incomplete. However, it throws some light on the problem and is presented in Table XVII.

TABLE XVII.—The Influence of Timothy on Succeeding Wheat Yields.

Plot	Wheat After	1st Year Bu. per Acre	2nd Year Bu. per Acre	3rd Year Bu. per Acre	4th Year Bu. per Acre
2	wheat	21.54	14.70	15.69	12.57
3	timothy	21.22	26.10	23.36	22.35
25	wheat	23.00		10.30	
27	timothy	27.00		13.80	
25	wheat		10.30	22.84	17.74
28	timothy		16.70	30.17	21.49

INCREASE DUE TO TIMOTHY

Plot	1st Year	2nd Year	3rd Year	4th Year
3	-.32*	11.40	7.67	9.78
27	4.00		3.50	
28		6.40	7.33	3.75
Average	1.84	8.90	6.16	6.76

*Decrease

The elimination of the yields in 1896 deprives us of the yields the second year after timothy on plot 27 and the first year after timothy on plot 28 and for this reason the table is incomplete for these years. In some years the best results are not obtained from seeding wheat on timothy sod and for this reason a cultivated crop or a flax crop should intervene. It is quite evident from the yields the second and third years after the timothy crop that it has a marked beneficial effect on the soil and that when introduced into a well balanced rotation it would prove profitable on the rich soils of the Red River Valley. As an average for all plots for all years the timothy has increased the yield of succeeding wheat crops 35.9 per cent.

THE RELATION OF ACTIVE ORGAINIC MATTER IN THE SOIL TO WHEAT YIELDS.

The soils of the Red River Valley are very high in their content of organic matter but some of these have been cropped for some time without the return of organic manures and the greater part of this organic matter is in the more advanced stages of decay. In this form it decays very slowly and has only a slight effect on the availability of the mineral elements of plant food in the soil.

There are two plots in Series I which show the effect of farm manure applied once in a four year cropping system. As an average, manure has produced an increase in the yield of all crops on each of these plots. Using the data in table IV as a basis for calculation each load of manure has been worth $1.07 when applied to corn in rotation with wheat on plot 6 and $1.04 when applied to millet in rotation with wheat on plot 10. However, it must be noted that these values are based on prices of farm products when they were much lower than at present. If we use the average farm price, December first, for the five year period, 1906-1910, we find that each load of manure on plot 6 has produced an increase of $1.40 worth of products and on plot 10 each load has produced an increase of $1.65 worth. The increase produced by the manure has been much greater during the last two courses than the first two as will be noted from the data in table III.

The most satisfactory method for calculating this increase is on the percentage basis.

TABLE XVIII.—The Increase in Wheat Yield Due to Farm Manure by Courses. 1892—1906.

Plot	Manure applied to	PER CENT INCREASE			
		1st Course	2nd Course	3rd Course	4th Course
6	corn	5.5	9.3	21.5	12.5*
10	millet	6.1	10.1	33.0	30.2*

* Three year period only.

There has been a gradual rise in the percentage of increase as the years have advanced with the exception of the last course. In this case, however, the yields of wheat for only two years are available and in one of these years (1905) the rainfall was the highest that has been recorded at the Experiment Station. It is well established fact that manure does not show as much beneficial effect in wet years as in dry years hence very little increase would be expected on the clay soil of the Red River Valley in a year that the rainfall was 17.22 inches in April, May, June and July as was the case in 1905. As 1906 was not an especially favorable year for wheat the yields were low and the increase less striking. If the third wheat crop in this course had been harvested the increase might have been as great as in the third course.

In the past very little attention has been given to the production, management and use of farm manures on many of the farms of the state. The manure produced by the work stock has been allowed to accumulate and remain exposed for years and the greater part of its fertilizing value lost. The failure to appreciate the value of manure has been largely due to the fact that under our climatic conditions organic manures do not decay rapidly enough to show marked results the first year or so.

Another mistake has been made in plowing under fresh manure for small grain. The manure should be applied when fresh to pasture land which is to be broken up or should be plowed under for corn which is to be followed by small grains. It is thus given a chance to decay in the soil before the land is seeded to small grains.

It is quite evident that the maintenance of the supply of organic matter has a very important bearing upon wheat production and that while the yield is increased the first few years to a marked degree the yeilds are more striking as the years advance indicating that the results are cumulative and extend over a period of years.

Furthermore, in the early years of the experiment the soil contained a high percentage of native organic matter in the early stages of decay and henec did not respond to the manure as much as it did later when this natural supply had been materially reduced by cropping.

Two plots in this series furnish us data relative to the effect of green manure upon the yield of wheat. The field peas which were seeded on plot 8 every four years were plowed under for green manure and the millet occupying a similar place in the cropping system on plot 11 was plowed under. By comparing the yields on these plots with those on plots 7 and 9 the increase due to the green manuring can be calculated. The increase expressed in percentage for the respective course is given in table XIX.

TABLE XIX—The Influence of Green Manuring upon Wheat Yields by Courses. 1892—1906.

Plot	Green Manured with	PER CENT INCREASE			
		1st Course	2nd Course	3rd Course	4th Course
8	field peas	-9.6*	-6.9*	33.2	17.6
11	millet	.6	-7.0*	10.0	10.5

*Decrease

If we consider the first two courses only, green manuring has been a failure but the later data shows it to be of marked benefit. In fact the increase of the last two courses has more than offset the decrease in the first two.

It is evident that the soil was so high in native organic matter in the early years that the artificial supply was unnecessary. As the years advanced, however, the original supply became depleted rapidly and an increase in yield results from the residual effects of the green manures plowed under in the early years of the experiment. The decrease in yield due to the green manuring in the first and second courses when field peas were used and in the second course when millet was used was for the most part caused by the low yield of the first succeeding wheat crop. As will be noted in table III the yield of wheat the second and third years after green manuring in these two courses has been practically the same on the green manured plots as on those from which the crop was removed. It is, therefore, clear that while the green manuring failed to produce any marked increase in succeeding wheat crops in the first two courses that it really had no deleterious effect upon the soil except in the first year after the green crop was plowed under. While it is possible that other factors were in some measure responsible for the decrease in yields it is no doubt largely due to the interruption of the capillary movement of soil water.

Under our climatic conditions plant tissues decay rather slowly and when plowed under in large amounts they separate the plowed soil from the lower soil layers for some time. When the soil is plowed early in the fall and seeded to wheat early in the spring not enough tillage is given to fill all of the open spaces between the plant stems and effect capillarity. As a result many of the wheat plants on such land suffer from lack of water even in periods of moderate drouth. This could be avoided if a cultivated crop like corn, potatoes or roots were planted the first year after the green manuring. The soil is prepared for these crops later in the spring and the intertillage given them extends well into the summer. More water is conserved in the soil by this means and the open spaces between the plant stems are filled in with soil. The result is that they decay more rapidly and the re-establishment of normal movement of soil water is more immediate.

Green manuring with field peas has produced a larger average increase than with millet. This is probably due in part to the higher nitrogen content of the peas part of which is obtained from the atmosphere by symbiotic fixation. There is some addition of organic matter to the soil when millet is plowed under but all of the nitrogen in the millet crop has been obtained from the soil and hence there is no actual addition of this element. The continued green manuring with millet or any non-legume would produce soil organic matter of a low nitrogen content. As time advances it would be necessary for decay to take place more rapidly in order to produce enough nitrogen to meet the demands of a maximum crop. While nitrogen is probably not as yet a limiting factor on the soils of the Red River Valley their native supply has been materially reduced and some attention should be given to its maintenance by the application of manures and the placing of legume crops in the rotation. Field peas and millet no doubt have other differences in their effect upon the soil such as the rate of decomposition and other chemical, physical and biological relations of the crops.

Further evidence relative to the influence of legume action is furnished by plot 19. This was seeded to wheat each year but two or three pounds of medium red clover seed was sown with it. The fall growth was plowed under to add to the soil supply of organic matter and nitrogen. Plot 14 was cropped exactly the same as plot 19 except that no clover was seeded with the wheat. Both plots were conducted during the eight year period (1892-1899). The yield was greater on plot 19 every year except 1892. As no clover had been seeded on the land previous to this time the beneficial effects of clover could not be expected the first year. The average increase of plot 19 over plot 14 was 1.81 bushels. At 85 cents per bushel, the average farm price December 1st. for the five year period (1906-1910), this would be worth $1.53 or enough to buy a little over six pounds of clover seed at 25 cents per pound.

CROPPING SYSTEMS SUITED TO RED RIVER VALLEY CONDITIONS.

The fallow in 1907 and 1908 and the production of a crop of winter rye in 1909 left the plots of Series I fairly clean for the new system of cropping which was inauguarated in 1910. The rotations outlined for these plots have been worked out from the data obtained in carrying out the old systems of cropping and are considered to be practical for various types of farms in the Red River Valley. Some plots have been set aside for continuous cropping with alfalfa and brome grass both for hay and pasture. There is one three year, one eight year and three seven years rotations but the greater number are five and six year systems suitable for live stock or grain farming. Table XX shows the cropping systems for each plot together with the yields for 1910 and 1911.

TABLE XX.—Revised Cropping Systems for Rotation Series No. I with yields for 1910 and 1911.

Plot No.	No. of years in the rotation	1910 CROP	1910 YIELD	1911 CROP	1911 YIELD	1912 CROP	1912 YIELD	1913 CROP	1913 YIELD
E. end of 1	Brome cont.	Brom grass	0.63 T	Brome grass	2.12 T.	Brome grass		Brome grass	
W. end of 1	B. cont. man.	Brome grass	1.63	Brome grass	3.30 T.	Brome grass		Brome grass	
2	cont.	Wheat	15.70	Wheat	6.96	Wheat		Wheat	
3	5	Wheat	21.70	Corn	32.20	Wheat		Barley	
4	5	Wheat	24.50	Corn	35.48	Wheat		Barley	
5	5	Wheat	21.00	Corn	35.12	Wheat		Barley	
6	5	Wheat	17.90	Corn	33.98	Wheat		Barley	
7	5	Wheat	21.80	Corn	30.55	Wheat		Barley	
8	5	Wheat	21.80	Wheat	7.55	Barley		Clover	
9	5	Wheat	20.70	Corn	31.37	W. Rye		Barley	
10	5	Wheat	17.60	Corn silage	4.21 T.	W. Rye		Barley	
11	6	Corn-Man	1.44 T.	Peas and Oats	2.60 T.	Mangels		Millet	
12	6	Corn	2.59 T.	Wheat	10.45	Barley		Clover	
13	6	Corn	2.73 T.	Flax	10.71	Barley		Clover	
14	6	Potatoes	76.00	Wheat	11.65	Barley		Alfalfa	
15	3	Corn	2.37 T.	Barley	32.75	(Clover) Peas and Oats			
16	6	Corn	2.62 T.	Wheat	10.55	Barley		Clover	
17	7	Corn	1.98 T.	Flax	2.09	Wheat		Barley	
18	8	Corn	1.72 T.	Flax	3.75	Wheat		Barley	
19	6	Alfalfa	No stand	Alfalfa	No stand	Alfalfa		Potatoes	
20	6	Alfalfa	No stand	Alfalfa	No stand	Alfalfa		Alfalfa	

TABLE XX. (Cont.)—Revised Cropping System for Rotation Series No. I.

21	6	Wheat	21.60	Corn-Man	Silage 4.06 T.	Wheat		Barley	
22	6	Wheat	18.60	Corn	Silage 3.73 T.	Wheat		Barley	
23	6	Wheat	17.20	Corn (Pasture)	Silage 3.10 T.	Wheat (Pasture)		Barley Pasture	
24	7	Barley	17.20	*Barley (Hay)	.93	*Barley (Pasture)		Pasture	
25	6	Barley	18 70.	*Barley (Pasture)	3.39	*Barley (Pasture)		Pasture	
26	6	Barley	23.60	*Barley	1.87	*Barley			
27	6	Alfalfa		*Alfalfa	No stand	*Alfalfa		Pasture	
28	Cont.	Brome		Brome grass	V. poor stand	Brome grass Pasture		Pasture	
29	Cont.	Brome		Brome grass		Brome grass Pasture		Pasture	

TABLE XX. (Cont.)—Revised Cropping System for Rotation Series No. I.

Plot No.	No. of years in the rotation	1914		1915		1916		1917	
		CROP	YIELD	CROP	YIELD	CROP	YIELD	CROP	YIELD
E. end of 1	Brome cont.	Brome grass							
W. end of 1	B. cont. man.	Brome grass							
2	cont.	Wheat							

TABLE XX. (Cont.)—Revised Cropping System for Rotation Series No. I.

3	5	Clover seed			
4	5	Timothy seed			
5	5	Timothy-Man			
6	5	Clover Hay			
7	5	Peas			
8	5	Potatoes			
9	5	Clover			
10	5	Clover			
11	5	Barley	Clover and Timothy		
12	6	Wheat	Wheat		
13	6	Wheat	Wheat		
14	6	Alfalfa	Alfalfa		
15	3				
16	6	Wheat	Wheat		
17	7	Clover	Wheat	Wheat	
18	8	Clover and Timothy	Hay	Wheat	Wheat
19	6	Wheat	Barley		
20	6	Alfalfa	Alfalfa		
21	6	Clover and Timothy	Pasture	Flax	
22	6	Clover and Timothy	Pasture		
23	6	Timothy	Pasture		
24	7	Pasture	Potatoes		
25	6	Pasture	Potatoes		
26	6	Pasture	Pasture		
27	6	Pasture	Pasture		
28	Cont.	Pasture	Pasture		
29	Cont.	Pasture	Pasture		

These experiments have not been conducted long enough to draw any conclusions but the effect of the preceeding crop can be noted by referring to these figures. As 1910 and 1911 were dry years, especially early in the season, no stand of clover, alfalfa or timothy as yet have been obtained and the rotation has necessarily been modified slightly but no change in the future cropping is to be made. Substitute crops will be used whenever necessary, for example, as no stand of clover was obtained on plot 15 in 1911 it will be seeded to peas and oats in 1912. The west half of plot 1 has been manured each year since 1905. This will be continued but the amount applied will be reduced somewhat to conform to the amount of hay produced on the plot. The amount of manure that will be produced in each rotation will be applied to the west half of each plot in the future. In most cases it will be applied to the corn crop but for the immediate course it will be applied as soon as possible in each rotation. Commercial phosphatic fertilizers will be applied in two or three cases in place of the manure.

It will be noted from the outline that each of these cropping systems is a complete rotation. Each contains a cultivated crop, each a legume or grass crop and each one or more small grain crops. The purpose of the cultivated crop is to conserve soil water, improve the structure of the soil thereby furnishing a more suitable media for the development of desirable soil bacteria, and to further the change of inert plant food into usuable form. The introduction of the legume crops, such as clover and peas, into the rotation is for the purpose of improving the structure of the soil, maintaining the supply of active organic matter in the soil, and the fixation of elementary nitrogen from the air by the bacteria which live in the nodules on the roots of these plants. Grasses serve the same purpose with the exception that there is no symbiotic fixation of nitrogen when they are grown. The cultivated crops, the legumes and grasses are all profitable crops in proper systems of farm management and should be the source of considerable income to the farm directly or indirectly. But as our soil and climate are favorable for the production of good yields of a high quality of small grains these should also have a place in the rotation. The income from these crops will be much greater when in a rotation with cultivated crops and legumes.

ROTATION SERIES II.

Rotation Series II was started in 1902. The object of this series was to determine the influence of various crops on succeeding wheat crops. Some of the cropping systems were duplicates of those on Series I and others were somewhat different. In order to obviate the discrepancies due to variations in seasonal conditions as much as possible each rotation was so arranged that each year in the cropping system would be represented every year. As the cropping was a four year rotation on all plots except the check plots there were four plots on which the same rotation was practised. The soil on which this series is located is black clay very similar to that on Series I. The virgin sod was broken about 1883 and from that time until 1892 the land grew wheat continuously. It was seeded to timothy and clover in 1892 with wheat for a nurse crop. A good stand was obtained and the land was left in hay until 1898. After the hay was taken off in 1898 it was plowed and the following spring seeded to wheat. Corn was grown in 1900 and oats in 1901.

In the spring of 1902 the field was laid out into 38 one-fourth acre plots 33 feet wide and 330 feet long. These plots were separated by a strip 12 feet wide. The end alleys are also 12 feet in width. Nine of the rotation plots and the two continuous wheat plots were started in 1902. In 1903 nine more were started, nine more in 1904 and the remaining nine in 1905. According to the original plan plots 1 and 38 were to be seeded to wheat continuously for use as check plots and nine systems of cropping were under trial as follows:—

PLOTS	CROPPING
1 and 38	Wheat continuously
2, 11, 20 and 29	Barley 1 year, wheat 3 years
3, 12, 21 and 30	Oats 1 year, wheat 3 years
4, 13, 22 and 31	Flax 1 year, wheat 3 years.
5, 14, 23 and 32	German millet 1 year, wheat 3 years.
6, 15, 24 and 33	Hog millet 1 year, wheat 3 years.
7, 16, 25 and 34	Corn (6 in. drills) 1 yr., wheat 3 years
8, 17, 26 and 35	Corn (3½ ft. rows) 1 yr., wheat 3 yrs.
9, 18, 27 and 36	Potatoes 1 year, wheat 3 years
10, 19, 28 and 37	Fallow 1 year, wheat 3 years.

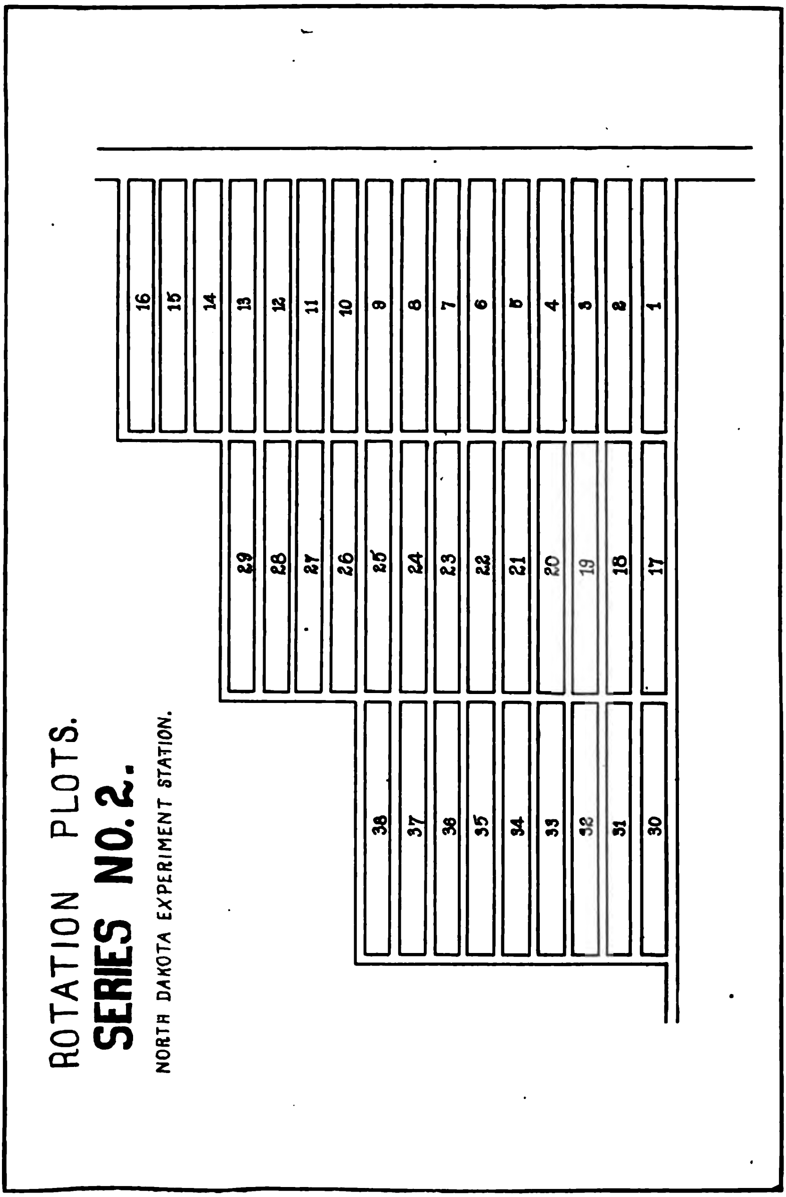
ROTATION PLOTS.
SERIES NO. 2.
NORTH DAKOTA EXPERIMENT STATION.

Plate III.

This plan was continued until 1909 when the plots on which barley, oats and flax were grown in rotation with wheat were dropped from the experiment on account of their extreme weediness. The continuous wheat plots became so weedy that they were also dropped. The rotation of drilled corn one year and wheat three years was also discontinued and a rotation consisting of corn one year, wheat two years, clover one year was put on in its place. The fourteen plots on which the other discarded cropping systems were practised have been used in a manuring experiment. There are some breaks in the records but the data presented in Table XXI shows in general what might be expected under field conditions on a soil of similar character.

TABLE XXI.—Yields in Rotation Series No. II. 1902—1911

	1902		1903		1904	
	CROP	YIELD	CROP	YIELD	CROP	YIELD
1	Wheat	12.20	Wheat	38.10	Wheat	10.30
2	Barley	50.20	Wheat	37.87	Wheat	15.20
3	Oats	48.80	Wheat	37.37	Wheat	16.30
4	Flax	21.80	Wheat	36.87	Wheat	15.60
5	German Millet	2.30 T.	Wheat	37.33	Wheat	15.60
6	Hog Millet	2.44 T.	Wheat	39.00	Wheat	14.40
7	Corn 6 in. drills	7.55 T.	Wheat	27.53	Wheat	13.90
8	Corn--3½ ft. rows	5.22 T.	Wheat	40.27	Wheat	13.40
9	Summer fallow plowed twice		Wheat	37.00	Wheat	15.40
10	Summer fallow plowed once		Wheat	36.73	Wheat	14.00
11	Emmer	49.8	Barley	47.83	Wheat	15.20
12	Emmer		Oats	67.19	Wheat	14.70
13	Emmer		Flax	15.39	Wheat	16.80
14	Emmer	53.0	German millet	plowed under	Wheat	13.90
15	Emmer		Hog millet	plowed under	Wheat	13.00
16	Emmer		Corn-6 in. drills	No record	Wheat	14.20
17	Barley		Corn-3½ ft. rows	No record	Wheat	11.40
18	Barley	46.90	Potatoes	No record	Wheat	8.90
19	Barley		Fallow	34.78	Wheat	6.00
20	Barley		Wheat		Barley	34.10
21	Barley		Wheat		Oats	64.00
22	Barley		Wheat		Flax	21.20
23	Barley		Wheat		German millet	.85 T.
24	Barley		Wheat		Hog millet	1.26 T.
25	Barley		Wheat		Corn-6 in. drills	Dry 2.33 T.
26	Barley		Wheat		Corn-3½ ft. rows	2.32 T.
27	Barley		Wheat		Potatoes	97.50
28	Barley		Wheat		Fallow	
29	Barley		Wheat		Wheat	15.00
30	Barley		Wheat		Wheat	Cut together Average yield 11.90 per acre
31	Barley		Wheat		Wheat	
32	Barley		Wheat		Wheat	
33	Barley		Wheat		Wheat	
34	Barley		Wheat		Wheat	
35	Barley		Wheat		Wheat	
36	Barley		Wheat		Wheat	
37	Barley		Wheat		Wheat	
38	Wheat	15.40	Wheat	33.87	Wheat	

TABLE XXI. (Cont.)—Yields in Rotation Series No. II.

1905		1906		1907	
CROP	YIELD	CROP	Yield	CROP	YIELD
1 Wheat	24.06	Wheat	20.20	Wheat	17.30
2 Wheat	35.50	Barley	*	Wheat	24.10
3 Wheat	23.86	Oats	*	Wheat	25.10
4 Wheat	22.66	Flax	4.30	Wheat	23.60
5 Wheat	22.33	German millet	*	Wheat	22.10
6 Wheat	16.46	Hog millet	*	Wheat	20.90
7 Wheat	25.60	Corn-6 in. drills	*	Wheat	15.20
8 Wheat	17.93	Corn-3½ ft. rows	*	Wheat	25.20
9 Wheat	19.86	Potatoes	*	Wheat	24.30
10 Wheat	17.13	Fallow		Wheat	23.00
11 Wheat	*	Wheat	17.80	Barley	31.60
12 Wheat	*	Wheat	17.40	Oats	39.00
13 Wheat	*	Wheat	16.20	Flax	11.80
14 Wheat	*	Wheat	18.30	German millet	*
15 Wheat	*	Wheat	18.40	Hog millet	*
16 Wheat	22.26	Wheat	19.80	Corn 6 in. drills	*
17 Wheat	29.26	Wheat	21.50	Corn 3½ ft. rows	47.54 4.7 T. St.
18 Wheat	27.06	Wheat	20.60	Potatoes	156.00
19 Wheat	26.06	Wheat	19.80	Fallow	
20 Wheat	27.86	Wheat	19.10	Wheat	27.50
21 Wheat	*	Wheat	22.20	Wheat	26.40
22 Wheat	*	Wheat	20.20	Wheat	21.20
23 Wheat	29.53	Wheat	19.50	Wheat	26.70
24 Wheat	*	Wheat	23.00	Wheat	27.20
25 Wheat	*	Wheat	19.80	Wheat	21.40
26 Wheat	*	Wheat	19.90	Wheat	23.60
27 Wheat	*	Wheat	22.40	Wheat	22.70
28 Wheat	*	Wheat	23.30	Wheat	20.50
29 Barley	34.33	Wheat	16.90	Wheat	21.50
30 Oats	34.40	Wheat	20.20	Wheat	26.10
31 Flax	16.00	Wheat	16.40	Wheat	25.20
32 German millet	1.64 T.	Wheat	22.80	Wheat	26.60
33 Hog millet	*	Wheat	25.80	Wheat	28.90
34 Corn 6 in. drills	*	Wheat	15.00	Wheat	31.40
35 Corn 3½ ft. rows	*	Wheat	19.60	Wheat	28.00
36 Potatoes	*	Wheat	21.00	Wheat	28.00
37 Fallow		Wheat	20.90	Wheat	29.00
38 Wheat	19.53	Wheat	16.30	Wheat	20.90

* No record.

TABLE XXI. (Cont.)—Yields in Rotation Series No. II.

	1908		1909	
	CROP	YIELD	CROP	YIELD
1	Wheat	No record	Potatoes	No record
2	Wheat	No record	Potatoes	No record
3	Wheat	No record	Potatoes	No record
4	Wheat	23.80	Potatoes	No record
5	Wheat	24.30	Wheat	No record
6	Wheat	21.60	Wheat	No record
7	Wheat	22.50	Corn 3½ ft. rows	No record
8	Wheat	25.30	Wheat	No record
9	Wheat	26.30	Wheat	No record
10	Wheat	24.60	Wheat	No record
11	Wheat	No record	Potatoes	No record
12	Wheat	No record	Potatoes	No record
13	Wheat	21.00	Potatoes	No record
14	Wheat	26.00	Wheat	No record
15	Wheat	27.60	Wheat	No record
16	Wheat	No record	Wheat	No record
17	Wheat	30.60	Wheat	No record
18	Wheat	30.90	Wheat	No record
19	Wheat	28.00	Wheat	No record
20	Barley	No record	Potatoes	No record
21	Oats	No record	Potatoes	No record
22	Flax	16.00	Potatoes	No record
23	German millet	No record	Wheat	No record
24	Hog millet	No record	Wheat	No record
25	Corn 6 in. drills	5.80 T.	Wheat	No record
26	Corn 3½ ft. rows	5.20 T.	Wheat	No record
27	Potatoes	50.00	Wheat	No record
28	Fallow		Wheat	No record
29	Wheat	No record	Potatoes	No record
30	Wheat	No record	Potatoes	No record
31	Wheat	18.70	Potatoes	No record
32	Wheat	25.00	German millet	No record
33	Wheat	22.60	Hog millet	No record
34	Wheat	26.40	Clover	No record
35	Wheat	22.50	Corn 3½ ft. rows	No record
36	Wheat	21.80	Potatoes	No record
37	Wheat	21.40	Fallow	
38	Wheat	No record	Potatoes	No record

TABLE XXI. (Cont.)—Yields in Rotation Series No. II.

1910			1911	
	CROP	YIELD	CROP	YIELD
1	Wheat	13.20	Corn	33.14
2	Wheat	16.30	Corn	23.42
3	Wheat	11.20	Corn	28.28
4	Wheat	18.00	Corn	23.25
5	German millet	No record	Wheat	5.66
6	Hog millet	No record	Wheat	7.60
7	Wheat	14.60	Wheat	3.33
8	Corn	1.32 T.	Wheat	5.93
9	Potatoes	48.66	Wheat	8.20
10	Fallow		Wheat	6.33
11	Wheat	14.30	Corn	30.57
12	Wheat	21.20	Corn	27.25
13	Wheat	13.00	Corn	26.74
14	Wheat	14.00	German millet	3.43 T.
15	Wheat	8.90	Hog millet	30.80
16	Wheat	12.00	Peas	1.10 T.
17	Wheat	9.60	Corn	21.37
18	Wheat	14.20	Potatoes	94.00
19	Wheat	15.50	Fallow	
20	Wheat	12.10	Corn	23.71
21	Wheat	22.60	Corn	29.25
22	Wheat	14.40	Corn	28.57
23	Wheat	15.20	Wheat	3.33
24	Wheat	11.30	Wheat	3.66
25	Clover	No record	Corn	22.68
26	Wheat	17.00	Wheat	3.80
27	Wheat	15.50	Wheat	4.80
28	Wheat	19.90	Wheat	5.13
29	Wheat	12.40	Corn	25.71
30	Wheat	14.60	Corn	26.40
31	Wheat	14.00	Corn	26.85
32	Wheat	20.00	Wheat	3.25
33	Wheat	9.60	Wheat	4.65
34	Corn-Silage	.80 T.	Wheat	7.33
35	Wheat	17.10	Wheat	6.00
36	Wheat	18.70	Wheat	4.00
37	Wheat	14.30	Wheat	4.53
38	Wheat	13.30	Corn	29.42

In 1909 the season was extremely favorable for weed growth and the grain was so weedy at harvest time that no yields were taken. Some very good yields obtained in the early years of the experiment and the differences in yield on the various rotations were less marked than during the latter part of the period. As the time advanced the increase of weeds became a serious problem and the weediness was greatest on the rotations in which there was no cultivated crop. The millets keep the land fairly clean but they are not as effective as the cultivated crops. As the original plan was discontinued in 1908 on some of the plots the data previous to that time should be used in comparing the various rotations as they were started. This data is summarized in Table XXII. The average of all years in which wheat was seeded in the respective places in the rotation is given in this table. In some years no yields are recorded on some plots but these years are included in calculating the averages because where no yields are recorded the crop was not worth harvesting. The average yield on plots 1 and 38 which were seeded to wheat every year are also presented for comparison. Owing largely to the fact that the land had been in grass for so long a period the yields in the early years of the experiment show very small increase over continuous crops.

TABLE XXII.—Comparison of the Yield of Wheat After Various Crops.

Wheat after	1st Year	2nd Year	3rd Year	Average
Wheat				17.69
Barley	20.32	11.16	17.21	16.23
Oats	16.23	12.92	16.91	15.35
Flax	19.11	16.96	19.69	18.59
German Millet	25.27	17.20	23.08	21.85
Hog Millet	21.05	17.58	21.16	19.93
Corn 6 inch. drills	11.97	21.97	23.30	19.08
Corn 3½ ft. rows	21.18	23.31	21.38	21.96
Potatoes	17.02	25.94	21.70	21.55
Fallow	19.10	23.39	19.71	20.73

The average of plot 1 in wheat continuously for period 18.33 bushels.

The average of plot 38 in wheat continuously for period 17.06 bushels.

The yield of wheat is greater the first year after German millet than after any other crop in this series. The yield the first year after corn in rows and hog millet rank next there being little difference between the two. The yield the first year after barley, flax and fallow are but little lower but it is significant in this connection that the barley and flax had become so weedy in 1908 that they were discontinued. The potato rotation was not started until 1903 and this acounts in part for the lower yield of wheat the first year after potatoes. The beneficial effect of the grass crop on succeeding wheat crops is quite noticeable and as the wheat crops after potatoes were a little farther removed from the grass crop than in the other systems the yields are a little lower than they would have been if the potato rotation had been started at the same time as the others.

The yield of wheat the first year after oats is the lowest with one exception and besides it was one of the weediest plots whent he original plan was discontinued in 1908. The yield of wheat the first year after drilled fodder corn was lower than after any other crop. The marked difference between this and wheat crops preceded by corn planted in rows and cultivated is significant.

The yield of wheat the second year after potatoes was higher than any other crop occupying a similar place in the rotation. The yield the second year after fallow and after corn were practically the same but a little less than the second year after potatoes. The wheat yield the second year after drilled fodder corn was only slightly less than when the corn had been cultivated two years previous. The yield for the second year after the other crops in this series was about the same and in some cases less than on the continuous wheat plots.

The results the third year after the various crops are quite similar to the second year after with two notable exceptions. The yields after the millets are again one of the highest and the third crop of wheat after drilled fodder corn outstripped the corn plots which had received cultivation.

The data indicates that when corn is drilled and no cultivation is given a large amount of water is used. This depletes the soil of moisture and the succeeding wheat crop does not have an adequate supply. The weed growth is kept down, however, and when the soil water supply is increased by the one years rains the second crop of wheat has enough water and as the land is fairly clean a good yield is obtained. It is evident that the beneficial effect extends even to the third crop of wheat.

The highest average yield was obtained when corn followed by three crops of wheat was the system of cropping. When German millet or potatoes were substituted for corn the average yield was only slightly less. Fallow, hog millet, drilled fodder corn and flax respectively ranked next as crops in rotation with wheat and the average yield of wneat in these rotations was higher than that of the continuous oats was placed in rotation was less than on the plots that oats was placed in rotation was less thn on the plots that grew wheat continuously.

The preceding data for Rotation Series II take into consideration the wheat crop only. While wheat constitutes the principal source of income the other crops modify the total value of produce somewhat. The rapid increase of weeds and wet weather have reduced the income of all plots quite materially by causing practically a crop failure in some years. However, by averaging the income from all four plots in each cropping system we can get a comparison of their merits.

While none of these systems are complete rotations and would fail to be profitable permanently the data obtained will show what influence each crop has had upon the annual income. By averaging the income for each plot and then averaging each cropping system we have the data presented in table XXIII. The farm price December 1st as given in the year books of the United States Department of Agriculture are used in making these calculations.

TABLE XXIII.—The Average Annual Income for Various Cropping Systems. 1902—1908.

Plots	CROPPING	Average Annual Income Per Acre
1 and 38	Continuous wheat	$11.83
2, 11, 20 & 29	Barley, 1 yr. wheat 3 yrs.	11.41
3, 12, 21 & 30	Oats 1 yr. wheat 3 yrs.	10.83
4, 13, 22 & 31	Flax 1 yr. wheat 3 yrs.	14.74
5, 14, 23 & 32	German millet 1 yr. wheat 3 yrs.	12.73
6, 15, 24 & 33	Hog millet 1 yr. wheat 3 yrs.	11.29
7, 16, 25 & 34	Corn (6 in. drills) 1 yr. wheat 3 yrs.	11.52
8, 17, 26 & 35	Corn 3½ ft. rows, 1 yr. wheat 3 yrs.	15.18
9, 18, 27 & 36	Potatoes 1 yr. wheat 3 yrs.	18.86
10, 19, 28 & 37	Fallow 1 yr. wheat 3 yrs.	11.14

It will be noted that potatoes in rotation with wheat give the largest income but of course the additional cost of producing the crop of potatoes will reduce the profits of such a system somewhat. Furthermore, such a cropping system does not keep the soil in good condition for potato production. The comparatively large income is nevertheless significant.

Corn planted in rows so that it could be cultivated in rotation with wheat ranked second to potatoes in average income. The other crops ranked in the following order:—flax, German millet, corn (6 in. drills), barley, hog millet, fallow and oats. Continuous wheat ranked fifth in annual income. It is significant that this was higher than five of the systems where other crops were grown with wheat. Only two plots were in wheat continuously but they were located at each end of the series and are as good representatives as could have been used.

THE INFLUENCE OF VARIOUS CROPS ON SUCCEEDING WHEAT YIELDS FOR THE 10 YEAR PERIOD. 1902—1911.

In as much as some of the original cropping systems were discontinued in 1908 the data presented in the previous discussions are for the years previous to that time only. Five of the original systems are still being carried and, we have three years cropping and two years yields to add to this data. The average for the 10 year period (1902-1911) are presented in Table XXIV.

TABLE XXIV.—The Influence of Various Crops on Succeeding Wheat Yields.

Plots	Wheat After	1st Year Bu. Per Acre	2nd Year Bu. Per Acre	3rd Year Bu. Per Acre	Average Bu. Per Acre
5,14,23,32,	German millet	19.45	13.05	16.83	16.44
6,15,24,33,	Hog millet	15.19	12.98	14.98	14.38
7,16,25,34,	Corn	16.26	17.57	15.18	16.33
9,18,27,36	Potatoes	14.00	18.69	10.51	14.40
10,19,28,37,	Fallow	14.15	17.67	15.10	15.64

The same differences as were noted for the early years of the experiment are seen in the above table although they are less marked. When German millet preceded wheat the yield was highest, corn ranking second. In the second year potatoes ranked first, corn second and fallow third. In the third year German millet, corn and fallow ranked first, second and third respectively. As measured by the average yield of the three succeeding wheat crops in the cropping system the five crops ranked in efficiency as preparation crops for wheat as follows: German millet first, corn second, fallow third, potatoes fourth and hog millet fifth.

SUMMARY.

1. This bulletin gives the details of the crop rotation experiments conducted on the black clay soil of the experiment station during the 20 year period, 1892-1911. During this period two sets of experiments have been in progress; Series 1 from 1892-1906; and Series II from 1909-1911.

2. The systems of cropping carried out in these experiments were continuous single cropping with wheat and 2, 3, 4, 5, 6 and 7 year rotations consisting of wheat and one or more other crops.

3. Taking the average of all the plots in Series 1 those on which a rotation was practised yielded 5.99 bushels of wheat more than those on which wheat was seeded every year. The increase due to rotation the first 5 year period was 1.51 bushels; for the second 5 year period 4 bushels and for the third 5 year period 12.46 bushels.

4. A simple change or alternation of crops is not always beneficial. In these experiments the yield of wheat was increased when it was preceded by corn, potatoes, mangels, rape, German millet, broom corn or hog millet, field peas, medium red clover and timothy. When preceded by oats, barley, spring rye or flax the yield was practically the same as when wheat was grown continuously.

5. While the beneficial effect of the various crops was very marked in the immediately succeeding crops in some years the best results were not secured until the second year, e. g. the first wheat crop after a cultivated crop sometimes had a high proportion of straw. In such instances the straw was usually soft and subject to attacks of rust which caused material reduction in yield and quality of grain produced. In a dry season there was little increase in the yields of wheat on timothy or clover sod but there was a marked increase in the second and third crop of wheat following.

6. The yield of wheat is increased when a cultivated crop, a legume crop or a grass crop is grown on the land in immediately preceeding years but the best yields are not obtained unless the rotation contains both a cultivated crop and a legume or grass crop.

7. In Series 1 the largest total income per acre was derived when the cropping system was corn (manured) one year, wheat three years. The second in rank was corn one year, wheat three years and the third was millet (manured) one year, wheat three years.

8. In Series 1 the largest income derived from wheat

produced was when the cropping system was millet (manured) one year, wheat three years. The second in rank was corn (manured) one year, wheat three years and the third was fallow (manured) one year, wheat three years. The fourth was corn one year and wheat three years.

9. In Series 1 the average yield of wheat for all plots was 19.02 bushels for the first 4 year period, 20.04 bushels for the second 4 year period and 20.78 bushels for the third 4 year period and 15.23 bushels for the three year period, 1904-1906.

10. All crops except spring rye and oats helped to keep the weeds in the wheat fields in check.

11. In some years the excessive rainfall materially reduced the yield and in two or three years drouth has been responsible for low yields.

12. The beneficial effects of crop rotation are most marked in a good crop year or in a dry year.

13. In Series II the highest average yield of wheat was produced when the cropping system was German millet one year, wheat three years. The second in rank was corn one year, wheat three years and the third was fallow one year, wheat three years.

14. The yield of wheat the first year after drilled corn was less than on continuous wheat land but the average of the second and third crops of wheat was practically the same as when the preceding corn crop was planted in rows and cultivated.

15. In Series II the highest avergage annual income was derived when the cropping system was potatoes one year, wheat three years. The second in rank was corn one year, wheat three years and the third, flax one year, wheat three years.

16. There was a profit from the application of farm manure. When applied to corn in rotation with wheat it brought about an increase amounting to $1.07 per load. When applied to millet in rotation with wheat each load produced an increase of $1.04. These valuations are made on the basis of the prices of farm products for the years in which they were produced. If we use the average farm price for the five year period, 1906-1910, the value would have been $1.40 per load in the rotation of corn and wheat and $1.65 per load in the rotation of millet and wheat.

17. The beneficial effects of manure were cumulative as is evidenced in the marked rise in the increase in wheat yield due to manuring as the years advanced.

18. Green manures failed to produce an increase in the yield of wheat in the first two courses of a four year rotation but there was a marked increase in the third and fourth courses. Field peas used as green manure produced a greater increase than millet.

19. The increase in yield produced by farm manure and green manures especially in the later years indicate that where our soils have been cropped with cereals continuously there has been a marked decrease in the supply of organic matter in the soil.

20. Two or three pounds of medium red clover seeded with wheat produced an average increase of 1.81 bushels of wheat per acre.

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NORTH DAKOTA AGRICULTURAL COLLEGE

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GOVERNMENT AGRICULTURAL EXPERIMENT STATION OF NORTH DAKOTA

BULLETIN NO. 101

Potato Warehouse Plans

BY

R. M. DOLVE

Any farmer, teacher or student in the State may have this bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
NOV. 1912

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FOREWORD

That North Dakota can make a success of dairying, an inspection of the districts where it has been tried should convince any fair-minded man. In Sargent County, for example, we find the dairy interests very successfully worked into the farming plan and the general farm conditions stimulated and improved by it.

In Morton and Oliver Counties which are among our newer prairie districts dairying is a thriving industry and the farmers following that line of production are successful and contented.

The Dairy regions of the world are rich and successful wherever the industry is carried on with reasonable care. Denmark is an outstanding example of it, among the Agricultural countries of Europe. Wisconsin, Iowa and Minnesota are neighboring states which show good results from dairy farming.

The practice of dairying brings a rotation of crops and the fundamental advantages which come from a diversified system of Agriculture. It brings in cultivated crops which destroy weeds, insects and plant diseases and retain soil moisture. It adds humus to the soil both by bringing in grass crops and by means of the manure which it furnishes. It maintains soil fertility. It provides a regular income for the family and engenders economy and thrift by keeping their accounts balanced monthly instead of annually. The dairyman usually keeps some swine as a means of utilizing his waste milk and this adds further variety to his production.

North Dakota has a very small number of milk cows in comparison with our neighboring states. Wisconsin has 9.4 cows per quarter section of farmed land; Iowa has 7.1 cows per quarter section of farmed land; Minnesota has 6.3 cows per quarter section of farmed land; South Dakota has 2.0 cows per quarter section of farmed land; North Dakota has 1.6 cows per quarter section of farmed land.

The income from dairying in these states is as follows:
Wis.-annual income from dairy products is $66,952,486.00
Iowa-annual income from dairy products is $40,035,748.00
S. Dak.-annual income from dairy products is $ 6,633,759.00
N. Dak.-annual income from dairy products is $ 5,302,656.00

Experiments carried out by this Station clearly demonstrate that one-fourth of the farmed land can be put into forage crops without reducing the quantity of grain produced and will in fact cause economy of production by giving the same number of bushels in fewer acres. Hence the number of dairy cows can be greatly increased without reducing the grain production.

Dairying forms a sustained agriculture by retaining its fertility and keeping all other productive features in the best condition known in practical productive agriculture.

The above facts alone furnish sufficient reason for presenting this bulletin, while the number of inquiries applying directly for help in forming organizations and in assisting new communities to get dairy projects under way form a need that should no longer be ignored.

So many mistakes have occured in organizing creamery associations that it seems to the writer that ample provision should be made for aiding them to make their start along conservative and businesslike lines.

This bulletin is prepared especially to supply information to those interested in effecting the organization of creameries and cow testing associations and to enable them to organize on lines which have proven successful in other districts.

J. H. Shepperd.

Organizing Cow-Testing Associations and Co-operative Creameries

INTRODUCTION.

The co-operative cow testing associations and the co-operative creameries are the two factors which have done as mch to build up the dairy industry in the older states as all other agencies combined.

These two organizations furnish the farmer the best means of increasing the output of his herd. At the same time he gets all of the profits in manufacturing and marketing of his produce. It is vitally important at this stage in the development of our dairy industry that the farmers get started in the right manner.

COW TESTING ASSOCIATIONS.

The only way to make profits in the dairy industry is to put it upon a sound business basis. That will necessitate the culling out of the unprofitable cows, by means of the scales, tester and record book, then feeding the rest upon feeds containing the proper milk making nutrients. Profits in dairying are realized only when the net returns exceed the cost of production.

It is a pretty well established fact that any cow producing less than 100 pounds of butter fat annually will be kept at a loss. At least half of the cows in the Northwest are kept at a loss, and the only way to detect these boarders is to keep records of the feed consumed and milk produced. But the great drawback is the fact that farmers will not take the time to do this of their own accord unless they have some incentive as is furnished by the testing associations through an expert who can give each of them personal assistance.

WHAT THE EXPERT DOES.

The expert is hired by the associations to visit each farm at least once a month to weigh and test the milk from each, keep records of production and the cost of production in such form that they can be referred to at any time. In addition, the tester, being an expert dairyman, assists the farmer to select the best type of dairy cows and to compound rations from those feeds containing the most milk making nutrients at the lowest cost

In that way, he assists the farmer's in putting his herd upon a sound business basis which increases the net returns per cow.

BENEFITS OF TESTING ASSOCIATIONS.

The greatest benefit from the organization of testing associations is the friendly co-operative spirit which it fosters among the farmers of a community. It tends to stimulate interest in farm management, the breeding and the feeding of other live stock. One of the direct results from these associations is to pave the way for breeding associations, or bull associations, for the improvement of pure bred cattle especially of community breeding.

The cow testing movement very often serves as an opening wedge for the organization of farmers' clubs which meet fortnightly to discuss live topics pertaining to the farm, stimulate friendly rivalry and foster a better social spirit in the community.

PLAN OF ORGANIZATION.

The usual way of starting an organization of this kind is to call a meeting in the locality where such an organization is desired to discuss the plans of organization and the details of agreement.

One of the first essentials is a sufficient amount of compensation for the man who tests the cows. The common plan is for about 25 farmers to get together, organize and hire an expert to do the testing. The usual charge to the farmer is one dollar to a dollar and a half per cow which necessitates from 350 to 400 cows to insure the tester a reasonably good salary. In some cases the tester furnishes his own means of conveyance, usually a horse and buggy. If so, the members have to furnish feed and stabling for the horse and lodging for the expert one day each month.

In addition, each farmer usually furnishes, a scale, a testing outfit and blanks or books necessary to keep a permanent record of each of his cows.

HOW TO PERFECT ORGANIZATION.

The following will furnish a plan of agreement and by-laws in common use. After a sufficient number of farmers have signed the agreement, they are then ready to hold a meeting and adopt permanent by-laws for the association.

AGREEMENT FOR ORGANIZATION.

Whereas, ... Co-operative Dairy Association has been organized for the principal purpose of providing means for the co-operation of its members in keeping records of the feed consumed, weighing and testing the milk of their cows periodically and for the improvement of the dairy interests, and WHEREAS, it is proposed by said association to engage a suitable person for that purpose as soon as enough subscriptions are obtained to warrant said association to engage such person, we the undersigned members of said association, each for himself and not one for the other, severally agree to pay to said association for that purpose, the sum of .... dollars a year for each cow set opposite our respective names. Said fee to be paid in semi-annual installments in advance, the first payment to be made as soon as such person is engaged by the association. Each one of us further agrees to furnish board and lodging for said person for at least one day each month and convey him to his next place of work or if said person furnishes his own conveyance, we agree to furnish feed for said person's horse at least one day a month. Said person shall not work Sundays, but shall have board and lodging over Sunday at the place where he is working Saturday.

Name	**Address**	**No. of Cows**
....	....	....
....	....	....
....	....	....
....	....	....

BY-LAWS OF THE ASSOCIATION.

ARTICLE I.—MEETINGS.

The annual meeting of this association shall be held at a place to be designated by the Board of Directors in .... on the .... day of each year at .... o'clock in the afternoon, for the purpose of electing a Board of Directors and for the transaction of such other business as may lawfully come before said meeting.

Special meetings may be called by the Board of Directors or by the President and notice shall be given by the secretary by mailing to each member a written or printed notice thereof at least five days prior to such meeting. Such notice shall state the object of the meeting and no other business shall be transacted there at.

ARTICLE II.—BOARD OF DIRECTORS.

Sec. 1. The Board of Directors shall consist of ..... members. They shall be elected at each annual meeting, the first election to be held on the .... day of .... A. D. 19.....

Sec. 2. The Board of Directors shall have the management and the control of the business of the association.

Sec. 3. Whenever vacancies occur in the Board of Directors by death, resignation or otherwise, the same may be filled without undue delay by the majority vote of the remaining members of the Board. The person so chosen shall hold office until the next annaul meeting or until his successor is elected and qualified.

Sec. 4. The Board of Directors shall meet on the .... day of each month, at such times and in such places as may be decided upon.

Sec. 5. A majority of the Board of Directors shall constitute a quorum at all meetings of the Board.

ARTICLE III.—OFFICERS.

Sec. 1. The officers of the association shall consist of President, Vice-President, Secretary and Treasurer.. The office of secretary and treasurer may be held by the same person. The officers shall be elected by the Board of Directors by a majority vote of the whole number of directors. The first election shall be held immediately after the election of the Board. Subsequent elections shall be held annually on the day of the regular meeting of the Board's next ensuing election, the day to be fixed by resolution of the Board of Directors.

Sec. 2. In case of death, resignation or removal of any officer, the Board shall elect his successor who shall hold office for the unexpired term.

ARTICLE IV.—MEMBERSHIP.

Any person may become a meuber by being accepted by the Board of Directors and complying with the requirements of the by-laws.

ARTICLE V.—DUES.

Each member shall pay a fee of .... annually to defray the expenses of the association.

ARTICLE VI.—AMENDMENTS.

These by-laws may be amended, added to or changed by a majority vote of all members present at any annual meeting or at a special meeting called for that purpose.

The Co-operative Creamery

Factors to Consider.

The first requisite for a successful co-operative creamery is a sufficient number of cows. With the kind of cows commonly found in the Northwest few creameries could hope to succeed rithout at least 400 cows within a radius of five miles of the creamery. The cost of building, equipping and operating a creamery will be the same with a few cows as with many. Unless a creamery does enough business to maintain the cost of operation and pay interest on the investment, the organization never can hope to succeed.

Next to a sufficient number of cows the important point to consider is the amount of capital required. Many communities are led to invest a large sum where conditions do not warrant it. Often unscrupulous creamery promoters will go among the farmers and persuade them to take shares merely for the sake of the enterprise. The object being to dispose of the shares. In many places throughout the state such creameries stand idle after operating but a few months.

HOW TO ORGANIZE.

The first step in organizing is to call a meeting of the farmers and business men in the locality where such an organization is desired. Arrange to have attend some disinterested dairymen from the Department of Agriculture, the State Dairy Commission or the Agricultural College who can familiarize every one with the details of creamery work. Next select temporary officers and appoint committees on: —

a. Canvas for cows and shares.
b. Location and selection of site.
c. Building and selection of material.
d. Machinery and equipment.
e. Plans for organization.

Allow these committees ample time to thoroughly investigate the situation and formulate their reports. Then call another meeting for reports of the various committees. Often it is advisable to send a couple of enterprising men to some locality where successful co-operation is known to exist and have them study into the details of the organization and report at the meeting. The strength of a co-operative organization depends upon the number of men interested in the business.

After the various committees have reported favorably the blanks necessary to form a corporation may be secured from the Secretary of State, then stock may be issued and transferred. Often a limit of four is put upon the number of shares held by any one individual. This insures a wider distribution of shares and a more effective organization.

AGREEMENT FOR RAISING MONEY.

We, the undersigned citizens of .... County, State of ...., do hereby agree to incorporate ourselves into an association to be known as the .... Co-operative Dairy Association. We further agree to take at the rate of $........ each, the number of shares set opposite our names and further agree at any time during the operation of the creamery, to furnish all milk and cream that we produce from the number of cows set opposite our names. In case there are not 400 cows belonging to those subscribing for shares or if less than $...... worth of shares is subscribed this agreement shall not be binding.

Name	Address	No. of Shares	No. of Cows.
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

ARTICLES OF INCORPORATION.

ARTICLE I.

Sec. 1. This association shall be incorporated under and subject to the laws of the state of ....

Sec. 2. This association shall be known as the .... co-operative dairy association.

Sec. 3. The object of this association shall be the manufacture of dairy products and to mutually aid and co-operate to improve and develop the dairy interests.

Sec. 4. The place of business of this association shall be in .... City .... County, N. D. but the directors may hold their meetings wherever convenience may require.

Sec. 5. This corporation shall organize and exist for a period of ninety nine years unless formally dissolved.

ARTICLE II.—OFFICERS.

Sec. 1. The officers of this association shall be a president, a vice-president, a secretary, a treasurer and three trustees who shall be elected at the regular annual meeting of the association. to be held on the last Saturday in December each year. Their term of office shall be one year and until their successors shall have been duly elected and qualified.

ARTICLE III.—DUTIES OF OFFICERS.

Sec. 1. The president shall preside at all meetings of the association, sign all certificates of stock, contracts or other instruments of writing and do other acts appertaining to the office. He shall have power to call special meetings of the association whenever the business of the association shall require it.

Sec. 2. The vice-president shall perform the duties of the president in his absence.

Sec. 3. The secretary shall keep a record of all meetings of the association and keep all accounts of the corporation in books to be provided for that purpose. He shall notify all shareholders of the annual meetings and shall furnish a detailed report to the annual meeting of the association of all business transacted. He shall compute the amount of milk and cream received, the amount of product sold and all moneys received therefrom and after deducting from the total receipts the percentage herein provided for as a sinking fund, and running expenses, on the ......th of each month, shall divide the remainder among the patrons of the association, proportionately to the mumber of pounds of butter fat furnished by each.

Sec. 4. The treasurer shall receive and receipt for all moneys belonging to the association and pay out the same only upon an order which shall be signed by the secretary. He shall give bond in such amount as the association shall provide.

Sec. 5. The Board of Directors shall consist of the president, vice-president, secretary, treasurer and three trustees whose duties hall be to audit and allow all just claims against the association.

The Board of Directors shall have power to supervise and enact the business of the association provided for under this charter subject to the limitations of their by-laws.

They shall cause the secretary to make in writing a report of the annual meeting of the association, setting forth in detail the gross amount of milk and cream receipts, the money receipts and disbursements togther with a statement of the financial standing of the organization and such other information as may be of interest to the patrons. They shall cause such a statement to be recorded in the minutes of the annual meetings.

ARTICLE IV.—MEMBERS AND PATRONS.

Sec. 1. The several members shall furnish all the milk or cream from all the cows subscribed by each in accordance with provisions in the by-laws.

Sec. 2. Patrons of the association, not members, may furnish such amounts of milk or cream as may be agreed upon by the Board of Directors. The association may receive all such milk or cream so furnished, manufacture the same, sell the product, and from the receipts deduct such percentage or amount thereof as shall be agreed upon by the association in Sec. 2 of by-laws or otherwise, the remainder to be distributed as provided in Article III, Sec. 3.

Sec. 3. The butter maker shall deliver no milk, cream, butter or other product of the factory except by order of the secretary or manager.

ARTICLE V.—VOTING.

Sec. 1. Each member shall be entitled to but one vote at any meeting of the association. Members may withdraw or new members admitted as provided by Sec. 8 of the By-laws.

ARTICLE VI.—AMENDMENTS.

Sec. 1. The Articles of Incorporation may be amended at any annual meeting or at any special meeting called for that purpose provided that two-thirds of all members present vote in favor of such change, and, provided further, that at least thirty days notice of such proposed amendment shall have been given in such manner as provided for in Section 9 of the By-laws or otherwise, by the Board of Directors.

Sec. 2. In testimony, we the undersigned incorporators have hereunto set our respective names this.......... day of .... 19....

....

....

Signed in the presence of

JOHN SMITH,
WM. BROWN.

STATE OF NORTH DAKOTA
ss.
COUNTY OF.................

On the .... day of .... A. D., 19...., before me a notary public within and foresaid county,

personally appeared ....
....
who being first duly sworn, acknowledged that they executed the foregoing articles of incorporation as their free act and deed and who are known to me to be the persons who executed the foregoing (said) instrument.

....

(SEAL) Notary Public

BY-LAWS of ASSOCIATION.

Sec. 1. BOND.—The treasurer shall give bond in the sum of.......... dollars, the bond to be approved by the board of directors.

Sec. 2. FUND.—Five cents (5c) per hundred pounds of milk and one-half cent ($\frac{1}{2}$c) per pound of butter fat received at the creamery shall be reserved to form a sinking fund.

Sec. 3. DILEVERY. Milk or cream shall be delivered to the creamery at intervals agreed upon between the board of directors and the patron.

Sec. 4. GRADING.—All cream accepted at the creamery shall be graded and paid for according to quality.

FIRST GRADE.—All sweet cream that is free from odors, of good flavor and in good condition shall grade first.

SECOND GRADE.—All sour cream reasonably free from odors, of reasonably good flavor, and in good condition shall grade second.

Sec. 5. PREMIUM.—To encourage improvement in quality of raw product, a premium to be agreed upon by the stockholders shall be given on each pound of butter fat from cream grading first.

Sec. 6. OPERATION.—The operator shall take for test a sample of the cream furnished by each patron.

Sec. 7. STOCKHOLDERS.—Any stockholder who shall when the association is operating a creamery, patronize any other creamery or otherwise dispose of his milk or cream, except for family use without the consent of the Board of Directors, shall forfeit his stock and all interest in the creamery.

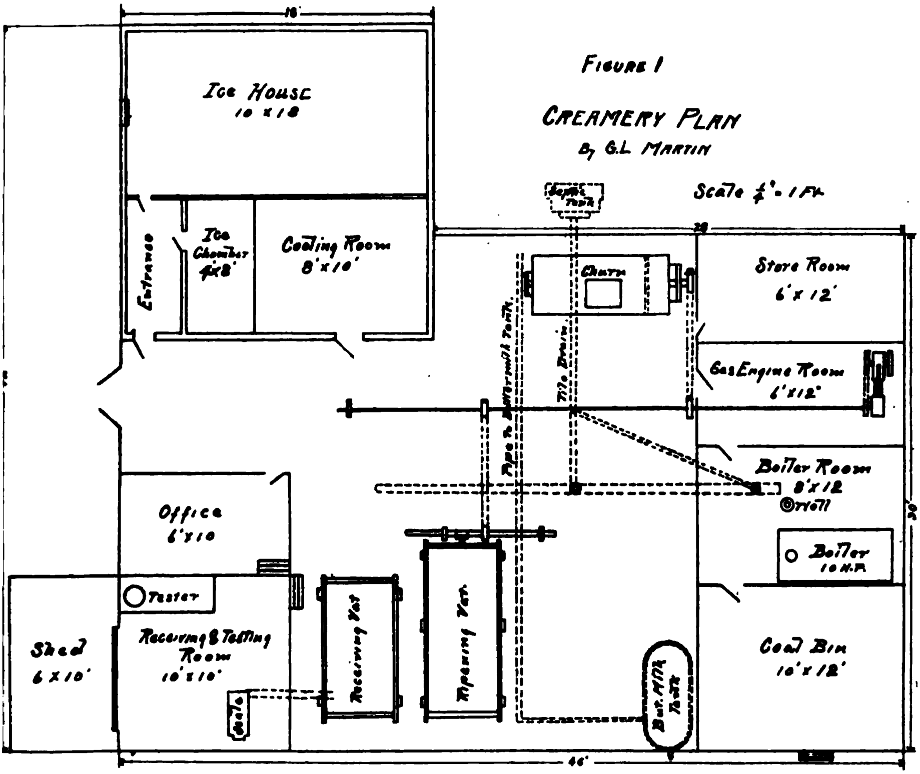
Sec. 8. SHARES.—Shares may be transferred from one person to another only by the order of the Board of Directors to the secretary to have such shares transferred on the books of the association. No person shall at one time hold more than four shares. The shares may range in price from $10 to $50.

Sec. 9. AMENDMENTS.—Notice of any proposed amendment to the constitution shall be posted at the creamery and sent to each patron at least ten days before such amendment is voted upon.

Sec. 10. QUORUM.—Ten members of the association or four of the Board of Directors shall constitute a quorum for transaction of business.

CREAMERY PLANS.

The figure No. 1 suggests the complete plans for a creamery together with water, cooling and drainage facilities sufficient to handle the products from 600 to 800 cows. The proper arrangement of machinery in the creamery greatly reduces the cost of equipment besides facilitates the handling of the products. To that end, provisions are made for office, testing room, store room, power room, and butter milk tank.



(Figure 1)

LOCATION.

In selection of a creamery site, it is well to choose a place centrally located, of easy access by the farmers, close to the ice supply and where good water and drainage facilities may be had. Often the creamery is located to advantage near to town in being close to the coal supply. It saves the expense of much freighting in bad weather both in getting supplies and marketing the produce. It often eliminates the necessity of the patron making an extra trip to the store hence will facilitate a more frequent delivery of cream in warm weather.

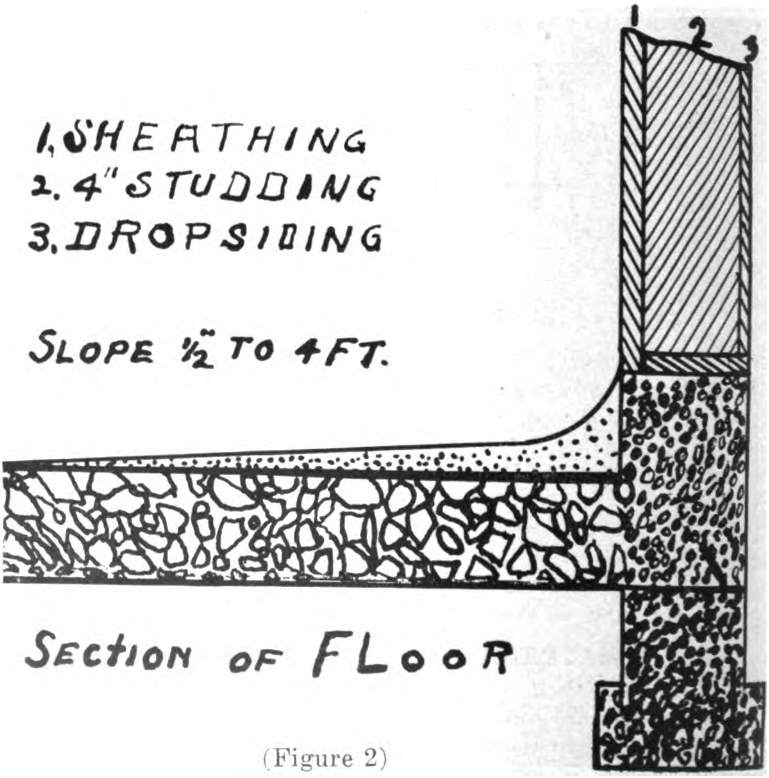
MATERIAL OF CONSTRUCTION.

Wood has been used largely in the past for creamery construction but it has several objectional features among which are its capacity to absorb and retain moisture. The creamery floor of necessity must be wet a greater part of the time. This soon causes decay and consequent odors which are readily absorbed by the cream and the butter.

The recent advance in cost of lumber and the utilization of cement for building has brought these materials nearly on a par with brick. While the initial cost of cement and brick are a trifle higher than wood it is more than offset in lasting qualities. They likewise largely eliminate the liability of fires and the necessity of insurance.

CREAMERY FLOOR.

Whether the creamery is built of wood, brick, or cement, the only practical material for a floor is cement. Often tile are used but unless they are laid by expert workmen the cracks between the tile will be repositories for dirt and are nearly impossible to keep clean. Cracks, corners, or depressions where dirty water may collect are



(Figure 2)

features to be avoided in floor construction. Figure 2 suggests a plan for laying the floor near the walls. This will give a rounding corner easily kept clean and prevents rotting of the wall. One half inch fall to each 4 feet will insure efficient drainage and keep the floor dry.

To keep a creamery floor warm in the winter time is often a difficult problem. However, if steam pipes are imbedded in the cement about 4 feet apart it will aid much in keeping the floor dry and warm, hence do away with rheumatism so common among butter makers. The expansion of the steam pipes must be accounted for when laying them in the cement, otherwise the floor may crack. The trenches can be made by using a 2x4 scantling, which may be removed before the cement becomes hard. The pipe may then be laid and filled about with sand, then the floor finished on the surface.

WATER SUPPLY.

One of the essentials in the location of a creamery is the water supply. Where good city water is available there is usually little trouble but where a well is to be depended upon care is necessary to provide good water. There is no one thing about a creamery that will lower the quality of butter quicker than poor water. The first requisite is plenty of clean water. If the utensils or the butter are washed in dirty water it cannot but have a deleterious effect upon the butter. This is perhaps one of the chief causes for poor butter for in many places the creamery is located on open, gravelly soil and unless the sewage is properly disposed of, surface drainage and seepage are sure to contaminate the well water.

COOLING ROOM.

A good cooling room is absolutely essential in connection with every creamery or cheese factory. Often butter has to be held for some length of time before marketing and it is too much of a risk not to have the cooling room properly constructed. Where only small amounts of products are stored as in the average creamery, the diagram in figure No. 3 will suggest methods of construction.

Since more satisfactory results can be had where butter is stored in a cool dry air than where vapor is present, it is well to have the cooling room and the ice chamber separated. If the partition (b) in figure 3 be raised eight inches from the floor and a deflector (a) arranged, the cool air at the bottom then can pass from the ice chamber to the cooling room and the warmer air at the top can pass from the cooling room to the ice chamber. As shown, it is well to have a slatted floor in the ice chamber made of 2x4's or 1x4's set on edge with spaces between to allow removal of the drippings from the ice as it melts and allow free circulation of air. Cement is the best for floor construction. In the cooling room it should be level but in the ice chamber a slope of 1 inch toward the gutter which is connected with the sewer will prevent water collecting.

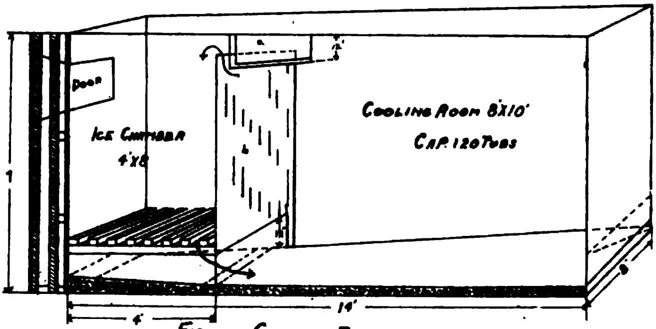


Fig. 3 Cooling Room

By G.L. Martin.

(Figure 3)

Figure No. 4 represents a section through the wall of a cooling room. It is recommended that dry shavings be well packed between the studding to assist in forming a dead air space.

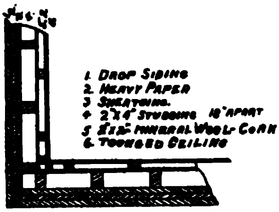


Fig. 4 Section Thru Wall of Cooling Room

(Figure 4)

ICE HOUSE.

The factors to be considered in building a creamery ice house are the amount of ice required for cooling cream, cooling butter, for ice cream purposes and the loss in storage and using.

One pound of ice will cool about 125 pounds of cream 10^0 F. To cool a thousand pounds from 80^0 to 50^0 F. will require about 24 pounds. Using that amount daily for 240 days will require approximately 3 tons. To cool the butter made from a 1000 pounds of cream will require about 9 pounds of ice per day or practically one ton for the given time. The rapid development in the use of ice cream and other frozen dairy products makes it advisable for all creameries to figure to that end. With what the patrons and outsiders will use, it would be safe to figure at least four tons more. The losses in storing and using ice are approximately as follows: storage 30%; cooling cream 20% and cooling butter 50%. With this loss, it will require about 16 tons for the average creamery.

One ton of ice well packed requires approximately 40 cubic feet of space hence the size of ice house may be figured acordingly.

10 tons	5ft.x8ft.x10ft.
12 tons	6ft.x8ft.x10ft.
14 tons	7ft.x8ft.x10ft.
16 tons	8ft.x8ft.x10ft.
18 tons	9ft.x8ft.x10ft.
20 tons	10ft.x8ft.x10ft.

ICE HOUSE FLOOR.

It is necessary to have the ground where the creamery and ice house stand well tile drained. After the tile are laid, a few loads of crushed rock, coarse gravel or cinders will greatly aid in keeping the ice free from any seepage thus preventing much loss.

WALLS.

The manner of constructing the walls of an ice house will have to be determermained by the material used in construction. In case they are single walls of brick or cement a space of 14 to 18 inches is left between the ice and the wall when packing. As the ice that is put in this space is packed thoroughly with sawdust which serves as an insulator. Where a frame building is constructed figure No. 5 suggests the arrangement of the several thicknesses of boards and of the insulation.

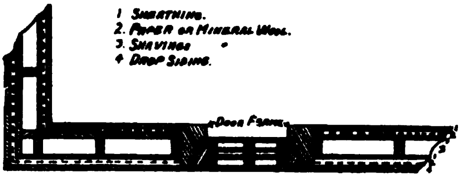


FIG. 5 SECTION THRU OUTSIDE WALL OF ICE HOUSE
BY G.L. MARTIN.

(Figure 5)

SEWAGE DISPOSAL.

It must be borne in mind at all times that creamery and cheese factory products are to be used as human food hence due precaution needs to be taken to properly dispose of all sewage and other sources of contamination. For creamery purposes a septic tank constructed similar to the following diagram is recommended.

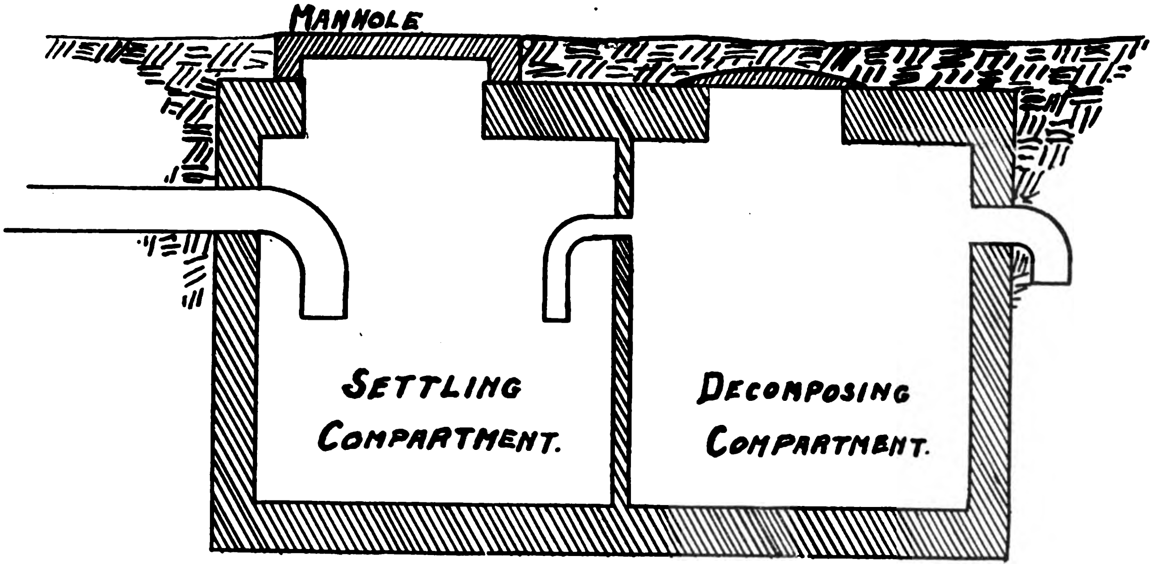


FIG. 6. SECTION OF SEPTIC TANK.

SCALE ½" = 1'

BY G. L. MARTIN.

(Figure 6)

LOCATION OF SEPTIC TANK.

It is necessary to have a fall between the creamery and the septic tank to insure rapid and complete drainage of all sewage. The tank may be located outside of the creamery whereever convenient. It is preferable to have it underground 12 to 18 inches to prevent freezing.

SIZE AND CONSTRUCTION.

A septic tank to be successful ought to be of sufficient size to hold the sewage for at least 24 hours before emptying in order that proper decomposition take place. For the ordinary creamery, a tank 8x12x4 feet in depth will answer.

The material of construction may be wood, brick, stone or concrete, preferably the latter. In making the tank, it needs to be as near air tight as possible with a small vent in the first compartment to allow some air to enter. It is advisable to have each compartment provided with a man-hole as shown in the figure. However, the opening in the second compartments may be covered with a board and then plastered over with cement in case it be necessary to effect an entrance at some later period.

COMPARTMENTS.

As designed, the first compartment constitutes the trap and settling space while the latter is the decomposing compartment. In connecting the gutter with the trap, the tile should extend below the surface of the sludge to prevent gases returning through the gutter.

The success of the septic tank depends upon the action of bacteria upon the sewage material. In order that bacterial action be not disturbed by occasional entrance of fresh sewage, several compartments are necessary. In the first compartment the bacteria require air but in the latter no air is required. The partitions need to be solid material and constructed according to the diagram.

Several openings in the partitions may be made but should be constructed as shown in the figure. Tile elbows can be built into the partition wall at intervals of 12 to 15 inches but care must be taken to have the opening K below the surface of the sludge several inches. When the sewage enters the settling compartmnt the solid material either floats or sinks hence with such an arrangement only the liquid material will pass to the next compartment. This is quite necessary in order to get good results.

EQUIPMENT.

The machinery necessary to properly equip a creamery will depend largely upon the volume of business to be done. It is advisable always to buy new machinery because the loss in efficiency of old or secondhand equipment will more than offset the additional cost of new machinery. There is no little difference in cost of creamery apparatus and in its efficiency that it is largely a mater of choice what makes are selected.

POWER.

The old ideas of creamery power have changed. When creameries were first started every creamery had one or two big power separators and a butter worker aside from the other machinery. These have been displaced by the hand separator on the farm and by the modern combined churn and worker so less power is necessary. The gas engine too has been improved and is replacing the large and expensive steam engine. One of the big leaks in creameries has been the power but by installing a 10 Horse Power boiler instead of a 20 Horse Power size as formerly, sufficient power will be had for the tester, pump, and other small machines and to furnish hot water and steam for cleaning and heating. A 10 Horse Power gas engine to run the churn and other heavy machinery instead of a 15 Horse Power steam engine will cut the cost of power in half. In some creameries the electric motor will be available in place of the gas engine so the 20 Horse Power hoiler and large steam engine will be out of consideration.

Often creamery associations are induced to install much expensive and needless machinery which could be added subsequently as required. The following list may assist in selecting the equipment to handle the cream form 400 to 600 cows:—

10 H. P. boiler.
10 H. P. gas engine.
600 lbs. platform scale.
300 gallon receiving vat.
Set sanitary pipe fittings.
400 gallon cream ripener.
Combined churn and worker.
Buter printer.
Vat strainer.
Churn strainer.
Butter milk tank.

Butter milk pump.
Tester and glassware.
Torsion balance for weighing cream.
Moisture testing outfit.
Half pint sample jars.
Corrosive sublimate tablets.
Floor brush and mops.
Thermometers.
Water hose.
Belting and shafting as required.
Wood split pulleys.
Steam fittings as required.

To the above list might be added an ice-crusher and ice cream freezer and packing cans where ice cream is made at the reamery. Many creameries find it a very profitable sideline.

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North Dakota Agricultural College

Government Agricultural Experiment Station

FOR

NORTH DAKOTA

BULLETIN NO. 103

Cropping to Flax on New Lands of Semi-Arid Land Areas

BY

H. L. BOLLEY AND W. L. WILSON

Any farmer, teacher or student in the State may have this bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
MARCH 1913.

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CROPPING TO FLAX ON NEW LANDS OF SEMI-ARID LAND AREAS

By H. L. BOLLEY and M. L. WILSON.*

Traction farming has introduced a new element into agriculture, and has brought into the work a new class of farmers. It also offers an opportunity for great improvement in agriculture or for methods tending toward deterioration and injury of the soils.

The men who are opening up these new lands, whether we speak of them as homesteaders, real estate men, or other business men, are men of intelligence. Accordingly, as they handle the land when they first break it, so will the harvest be in the near future. This cropping of the new lands can be done in the right way, or it can be done in the wrong way. It is hoped to present in this pamphlet in a concise manner the

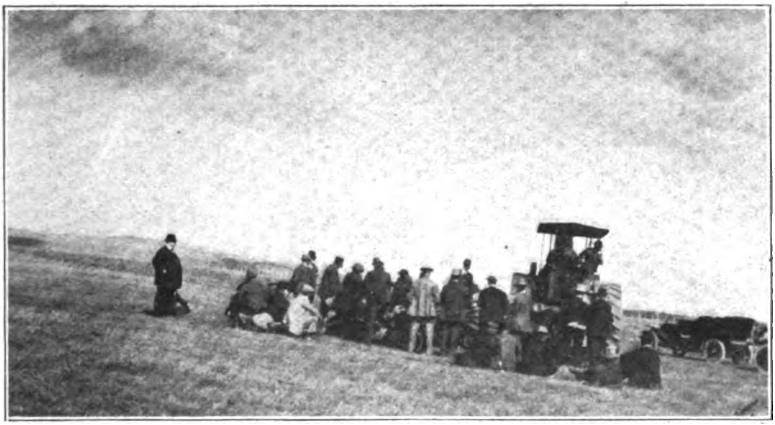

Fig. 1—Getting ready to place a new piece of the world's unworked land into crop. The picture indicates the very great interest now taken in working up the remaining areas of native sod.

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The manuscript was prepared and the circular has been edited by H. L. Bolley, Botanist and Plant Pathologist of the North Dakota Station, after having visited the fields in company with Mr. Wilson.

This publication, therefore, represents the joint conclusions of the authors. The circular is intended chiefly to be a picture book representing best methods for work on new land of the semi-arid plains of the northwest.

methods of cropping to flax on new lands which are most suitable for those areas which are described as semi-arid. It may also be of some interest to those who are working upon those types of land which may be strictly classed as "dry land" farming areas.

Diseases: The diseases of the flax crop are very serious. They are caused by root, seed and stem injuring and leaf modifying organisms which are capable of maintaining themselves in the soils for a number of years after they have once been introduced thru improper seed or other methods. Such diseases are very destructive to the crop when under best conditions, and, of course, are more destructive under poor conditions of cropping. If the fertility, or the moisture content, of the soil is low, or abnormal, these diseases which destroy the roots are all the more effective in preventing the crop from producing a pay yield. It is therefore of great importance that the methods of cropping with reference to diseases be correct.

Fig 2.—Teaching a group of men how to recognize the flax disease which infect the soil and bring about crop deterioration.

The organisms which produce the flax diseases are plants and must have certain growth conditions. Therefore, tillage, moisture and types of fertility do largely affect their development. Later, we shall see that the conditions of tillage most suitable for the development of the crop, which have in the past tended to produce large yields, have been largely beneficial because they have tended to keep these organisms in control.

What Must Be Done:

1. The soil must be properly broken and tilled to conserve moisture.

2. It must be properly packed and tilled so as to reduce the development of any parasitic fungi and also to give the roots of the flax crop the best possible growing conditions.

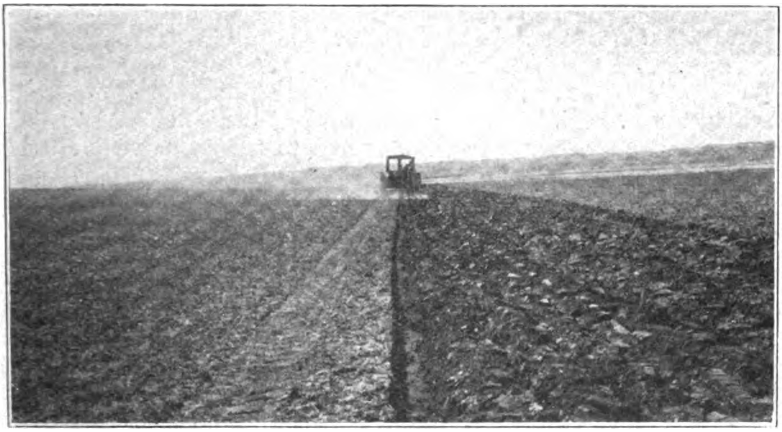

Fig. 3—Ripping up the sod. It is wrong to do it in this way. The soil will dry out. It should be *packed,* harrowed and worked down at once.

3. Seed must be so selected, graded, and treated as to prevent much introduction of disease into the soil.

4. Such crop rotation should be conducted that in case a certain amount of disease is introduced, it will die out.

5. Such steps should be taken as to preserve soil texture and fertility.

Figure 3 shows an outfit doing a good job of plowing, but it should not be done without the packer immediately following. Notice how the dust is blowing. It is evident that the wind and the dry air will soon take all the moisture out of the fresh turned soil. The way to save that moisture is to drag behind that outfit a very heavy packer, and behind that a harrow or other tool which will leave a light mulch on the surface, one which is rough enough and so firm that the wind will not start the dust cutting. A farmer who has only a team to work with should not plow faster than he can pack or harrow down the same day.

The Root and Seed Diseases of Flax: If one expects to succeed with the culture of flax, he must take into consideration the characteristics of the root and seed diseases of the crop. He must learn to know them in the field, and to know the condition or portions of the soil in which they are most destructive. He must learn to recognize the types of seed which are liable to introduce diseases. The sick plants have a very characteristic appearance. When a field has become infected, the diseases tend to kill out the plants in spots. The plants in such areas come up yellowish, die early and wilt and blight very characteristicly. On new lands one often finds scattering sick plants in the drill rows which have been introduced by the seed. If flax is allowed to follow flax, wherever a sick plant stands the first-year, the next year there will be an enlarged area of "flax-sick" soil.

Fig. 4—Elevator agents are able to meet and talk to farmers every day. An expert showing a group of elevator men how to select the best seed flax for sowing purposes.

Flax canker is a disease which accounts for the breaking over of plants near the ground line which many farmers have attributed to the action of insects such as ants. The plants which break over were in most cases internally diseased in the seed before the seed was planted. When the ground becomes thoroughly sick with flax canker, the plants are yellowish and weak and sickly in the spring, and later tend to dry up when the hot weather sets in.

Figure 2 illustrates one of the methods taken by an expert to explain the characteristics of diseases to groups of farmers and other people. Elevator men are particularly interested in proper methods of farming. Their business depends upon the amount of crop which the farmer has to store. They often buy and sell seed for sowing purposes and are in fine position to select the seed which is of the best quality for this purpose, One of the reasons why the new lands of the northwest have been so rapidly thrown into a "flax-sick" condition is the fact that the newcomers have not been able to procure fit seed. They usually go to the elevator and buy any mixed lot that may happen to be there, which may or may not be a badly diseased lot. The authors wish most emphatically to recommend that the elevator companies instruct their agents to select seed from the best crops grown by the local farmers. This should be set aside in a separate bin or bags. In so far as the elevators enter the seed business, they should use this sort of seed to sell back to the farmers or to newcomers. In

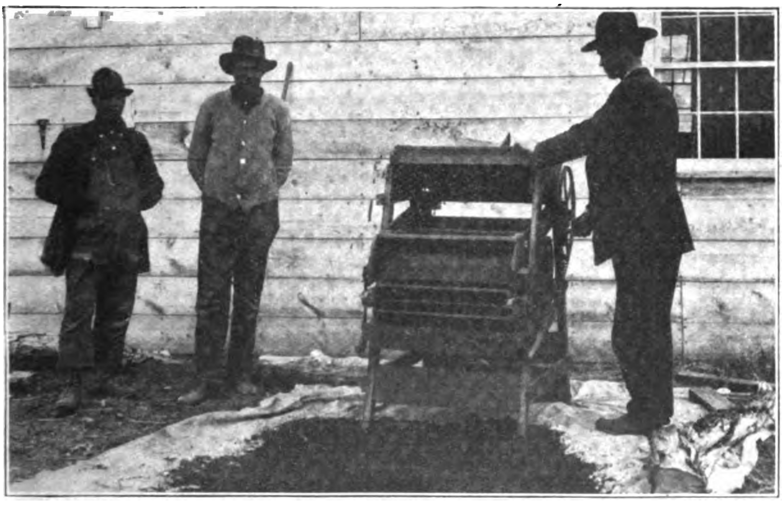

Fig. 5—Grading flax seed preparatory to treatment before sowing. One can not escape introducing flax wilt, flax canker and other flax diseases into the new soil if he fails to grade to best plump seed.

this manner the managers will be able to help in the **conservation of the purity of the soil which, so far as the flax crop is concerned, is all important.**

Grading Flax Seed: What we have said regarding the elevator agents and others interested in the buying and selling of seed for sowing purposes applies directly to the work of the individual farmer who is saving his own seed. He should save only the best, most mature, bright, properly colored plump seed, and should thoroughly grade it to remove the straws, chaff, dirt particles, and immature or shrivelled seeds. We have never seen any sample of flax seed that did not contain some diseased seeds due to wilt, canker and other root destroying flax diseases. However, if nice, bright, plump seed has been selected, saved dry and properly graded to blow out the light weight seeds which may chance to be present, the number of internally diseased seeds which may be present will be reduced to a minimum.

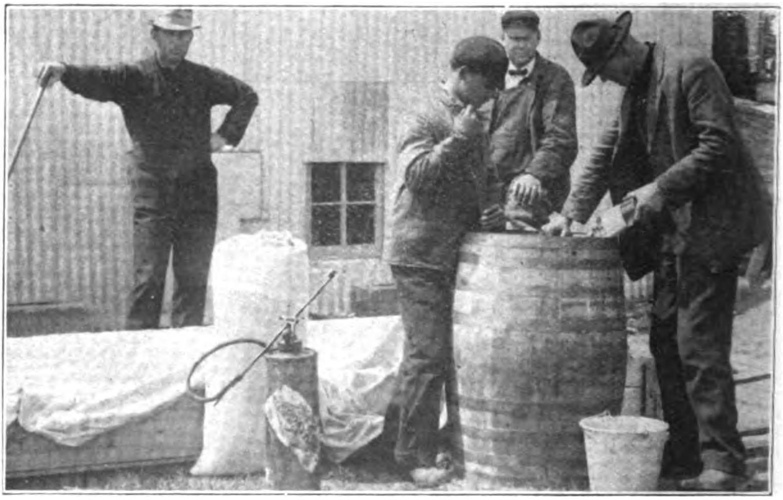

Fig. 6—Preparing the solution for disinfecting flax-seed for use on new lands. One pound of full strength formaldehyde is used in each 40 gallons of water. *All seed should be treated.*

Treating or Disinfecting Flax Seed: All flax seed, no matter what the variety, whether called "wilt resistant" or not, no matter how bright and plump or how well it has been

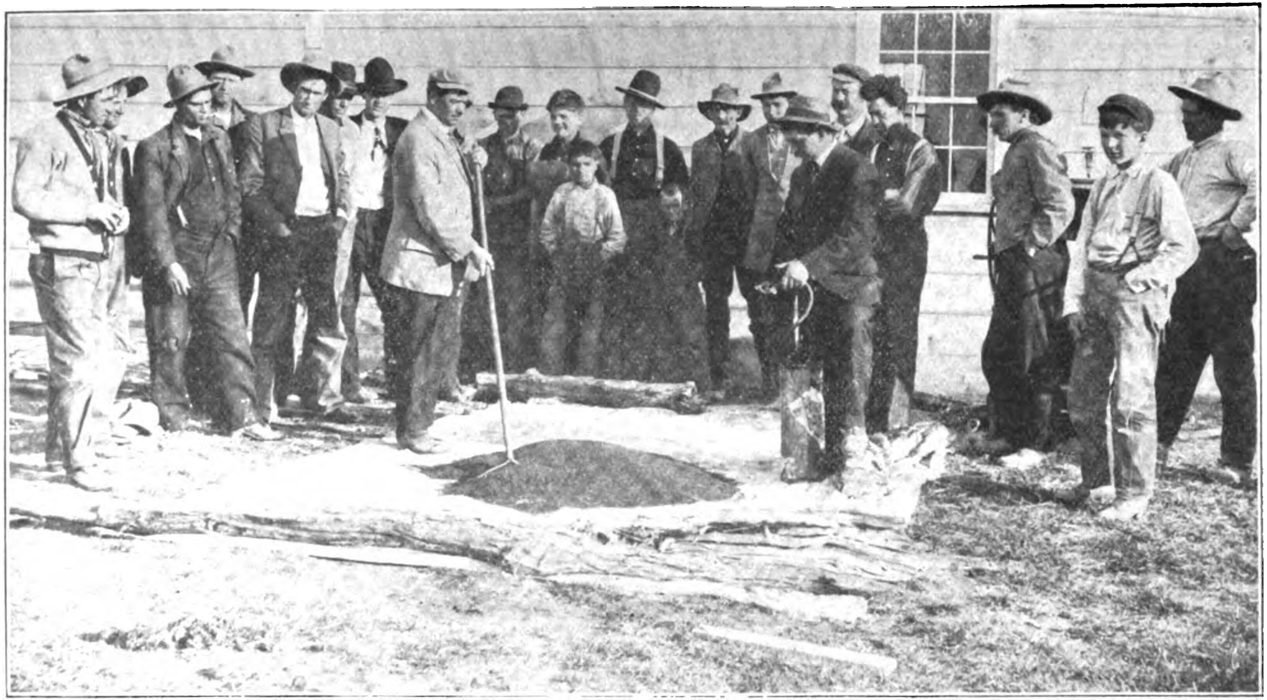

Fig. 7—Treating flax-seed on canvas in the open air. Raking and spraying method. A fine spray of the solution is thrown on the grain while it is evenly raked over. All seed should be selected and graded to plump form and bright color before treatment.

graded, should be thoroughly treated or **disinfected with** formaldehyde before it is sowed upon the land. **The purpose** of such treatment or disinfection is to destroy the very minute spores of disease which may be dusted over or scattered upon, or included in the hulls of the flax seed. **Use the standard strength formaldehyde and sixteen ounces advoirdupois to each forty gallons of water.** Wet the flax seed thoroughly in any manner which you see fit in which you can do the work and yet not have the seeds mat together.

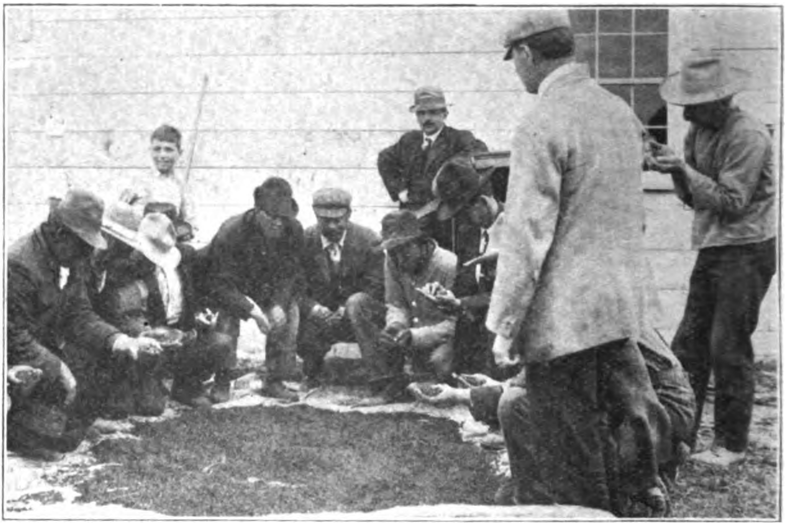

Fig. 8—Examining the flax-seed to learn when sufficiently treated. All seeds should be evenly wet or thoroly dampened over entire exterior, but not wet enough to cause the mucilage to begin to form.

Our figures 6, 7, 8, and 9 will show you some of the methods and steps of the procedure. It is easier to treat flax seed for sowing purposes than it is to disinfect any other type of seed grain. Remember, the grains must be thoroughly wet or evenly wet over the entire surface so that each grain has received the moisture. It can be done if the grain is evenly raked, shovelled or stirred during the time when a fine forceful spray is being thrown upon it. The most successful way and most economical way is to prepare a box or boxes with handles which can be easily handled. Then do the treatment in the open air in the field at the time of seeding. (See

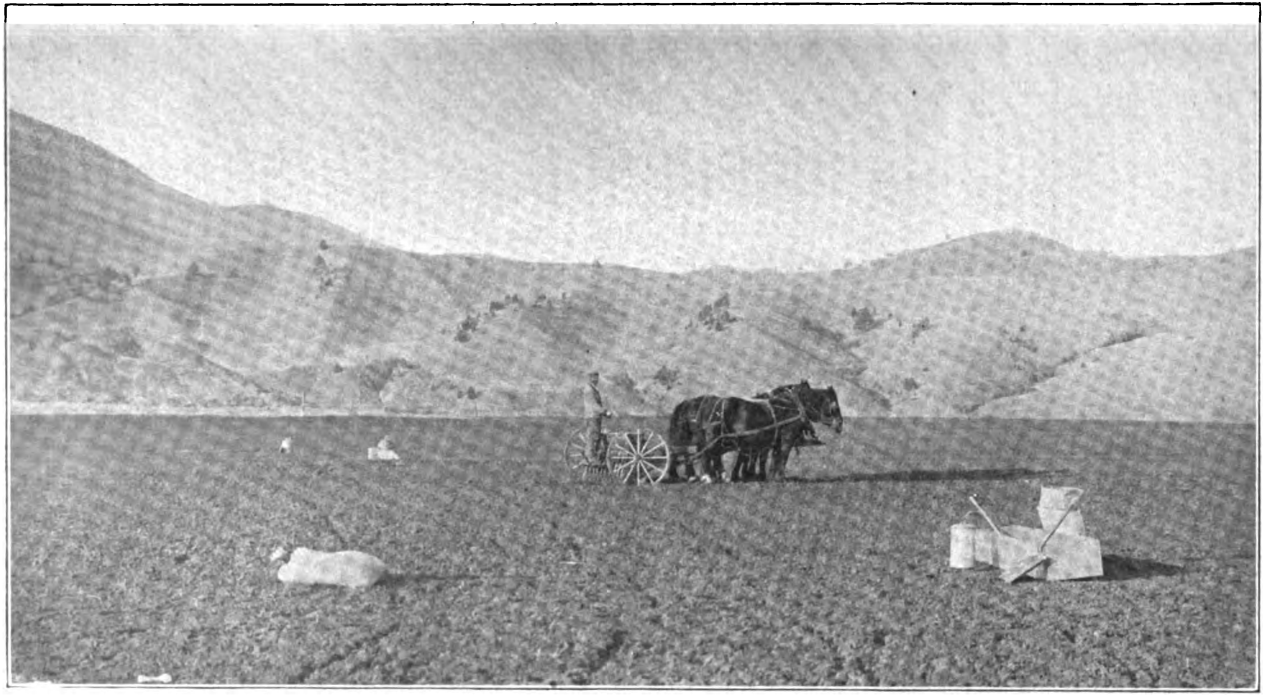

Fig. 9—Treating seed in the field as the seeding is done. This is the latest and most approved method. It gets best results.

Fig. 9) The best form of box is perhaps shown in figure 10. Best results have been obtained by all those farmers who have sowed the seed while it is yet damp, not waiting for it to become thoroughly dry. If it is done in a wagon box, or other large box, as shown in Figure 6, or is treated upon a large canvas, as shown in Figures 7 and 8, the grain can be left piled in a pile for a time covered by blankets or canvas, and the seed will take up the excess moisture. Fine results have been obtained by those who have treated the seed once, then allowed it to become nearly dry and then have given it another treatment. In this manner they are able to use about twice as much solution and in all probability succeed in soaking up the seed coats or hulls in such manner as to do a better killing of the fungi which are there included.

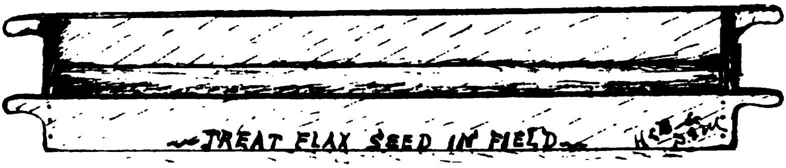
TREAT FLAX SEED IN FIELD

Fig. 10—A handy form of box for treating seed in the field thru spraying and raking method.

Preparing the Seed Bed: The flax crop needs a good even continuous deep supply of moisture coming from below thruout the entire growth season. It is a lover of hard, firm soil, therefore, the soil must be packed down, excluding essentially all air spaces. All of the fungi which attack the roots of the flax crop are air loving organisms. They, therefore, are lovers of a loose, mellow, open soil. They cannot thrive well in a compact, properly constructed seed bed. A firm seed bed tends to confine the activities of these roots destroying organisms more nearly to the surface and thus tends to check destructive effect because they become exposed to the destructive agencies of the sun and air drying.

In all those regions of the western Dakotas and eastern Montana and similar regions, in which there is sufficient rainfall during the winter and spring months to mature a crop and the soil is of such texture as to conserve the moisture, the best crop will be produced by such methods of handling the sod as will allow of the plowing and working of the ground and the seeding to be done at one and the same operation, or at such time as to essentially meet these requirements. Our figures 11 to 18 inclusive show most of the essential steps. We

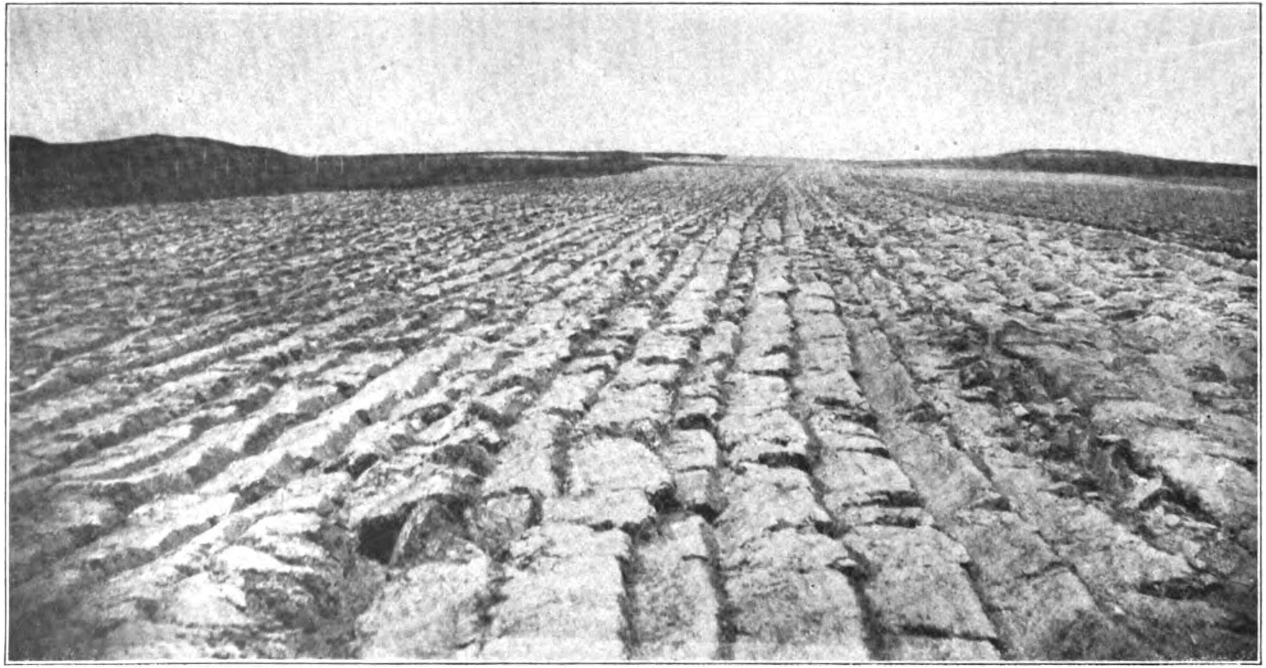

Fig. 11—A fair job of breaking, but should have been mashed down flat with heavy packer. Notice how the furrow slices over lap so that the grass side does not lie flat on bottom of furrow. The plow should not turn more than it cuts off clean.

would especially call attention to Figure 12, the rough plowed land with the air spaces underneath the sods not only allow them to thoroughly dry out and become impervious to the roots of the flax plant, but results in the loss of a large portion of the seed, and eventually brings about a condition under the sods which proves very destructive to the crop. As the roots of the flax perforate the sods, they come into the open air chambers, and by the action of wind and air are quickly injured, being alternately dried out and wet up according to conditions. These sub-sod air spaces are particularly destructive to the flax crop when there is any disease sown with the seed, for they, at times, form damp chambers in which the moisture from the sub-soil collects on the decaying vegetation underneath the sod and the flax disease producing organisms or molds develop in quantity in much the same manner that ordinary bread mold developes upon wet bread under a tumbler or other bell glass. The result is that the young roots of the flax plant, as soon as they come into these damp chambers are attacked by such molds and damp off so that they are not able to penetrate the sub-soil. Under such conditions, the first hot or dry wind which comes along readily blights the crop. Though it may appear to have a strong stand of sturdy straw sufficient for a large yield, when harvest time comes, it is often found that the seed is shrivelled and the yield very greatly reduced.

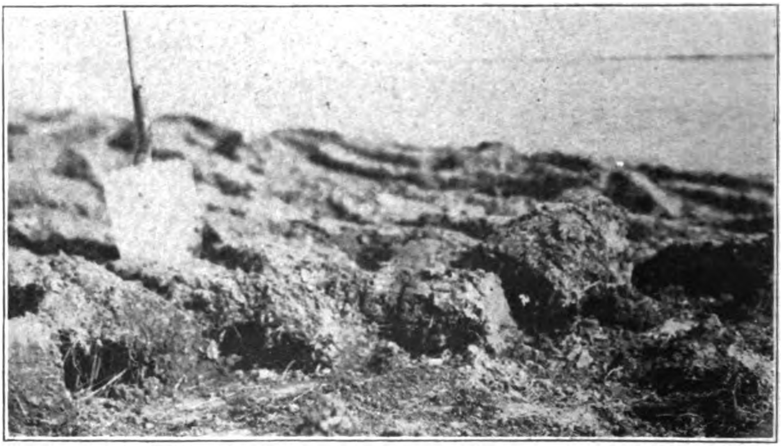

Fig. 12—This photo shows a roughly broken sod with furrow slices cut across. Notice the holes and air spaces between and under the sods. This is bad for the coming crop.

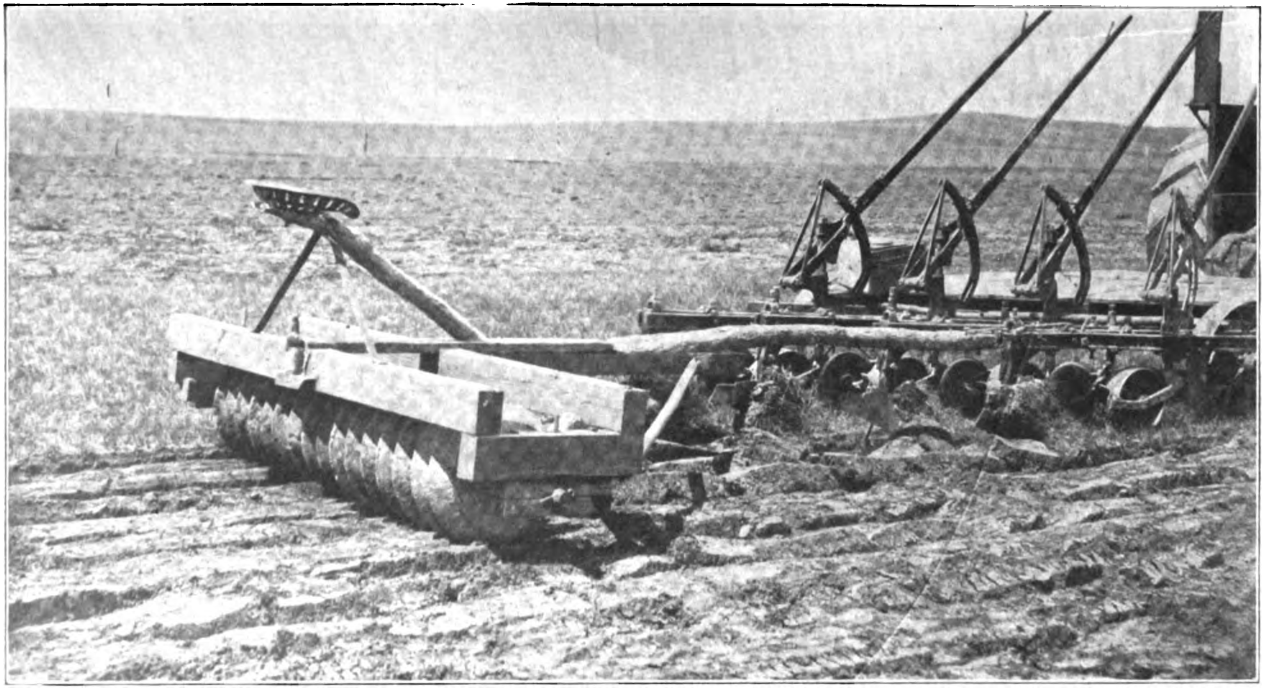

Fig. 13—Breaking and packing with a home-made cement roller. This roller does the work. This roller weighs 280 pounds per running foot.

The manufacture of packing tools has not kept pace with the demand with regard to weight. Makers have been afraid that farmers would not buy heavier tools, and, as a result, the ordinary packers on the market are not heavy enough, or properly constructed to allow them to be weighed in such manner as to mash down the sods. We call attention to the

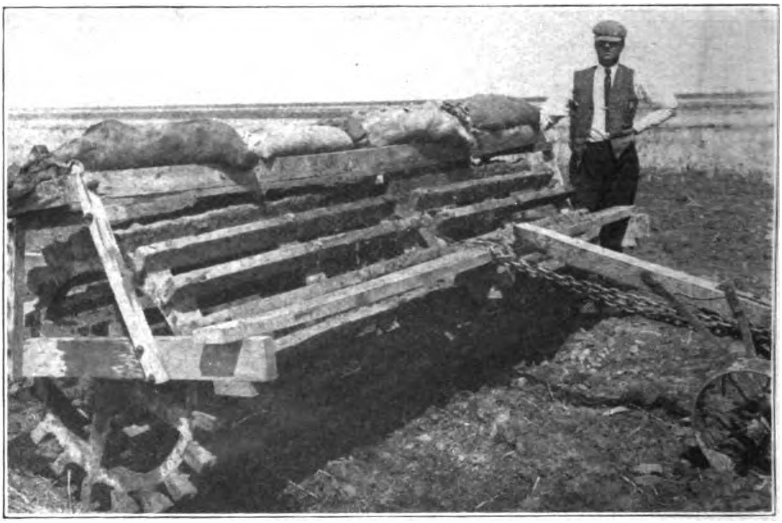

Fig. 14—Another home-made packer of large form, made of 2½ x 8-inch plank set into heavy bull wheels. A packer must be heavy or else loaded.

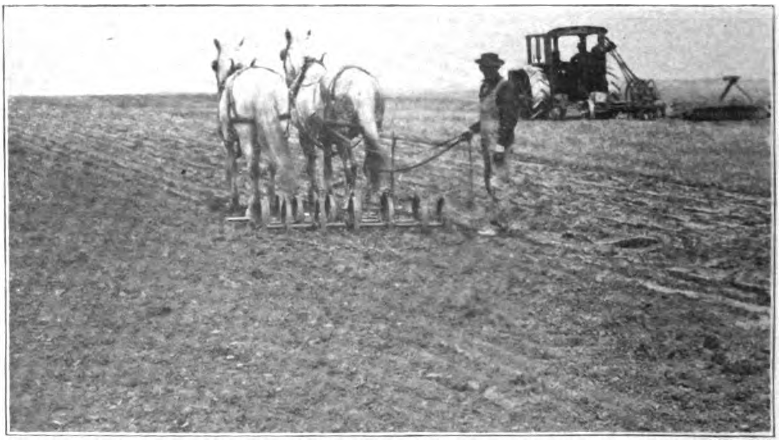

Fig 15—Homesteader finishing the seed bed on well packed sod—using spring tooth harrow. This man made almost an ideal seed bed.

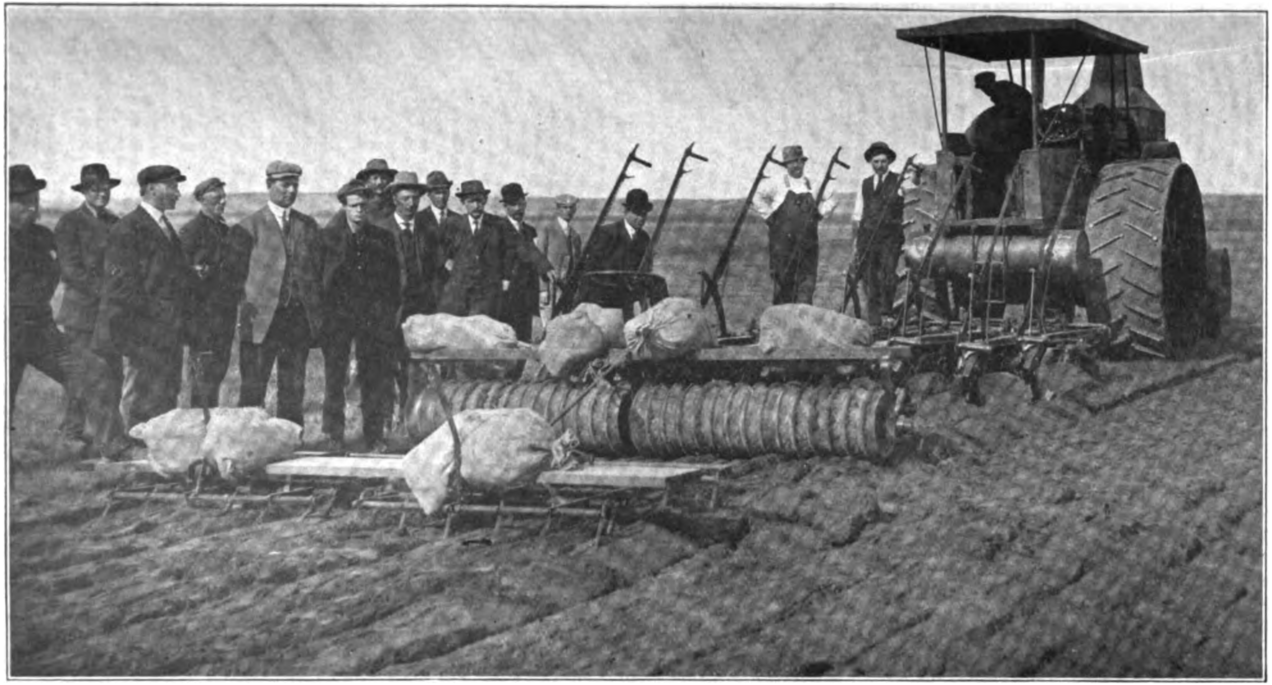

Fig. 16—Trying to work down a sturdy sod with too light tools. Doing best they could under the circumstances. Better buy or make a heavier packer.

work done by a Home Made Cement Roller shown in Figures 13 and 18. Figure 18 shows the manner in which the deep plowed sods can be made to lie with their grass faces firmly in contact with the underlying sub-soil.

When the roots of the young flax plants pass thru such sods, they come into immediate touch with the sub-soil and go on downward so that it takes more than an ordinary hot wind to have any effect. There are no damp chambers left under the sods for the accumulation of molds and other destructive root destroying organisms. The moisture can also come freely from the sub-soil upward to the surface. A properly constructed shallow mulch on the surface completes the seed bed and tends to prevent the evaporation of the moisture. The seed bed should be so firm that when the discs of the drill are run over it, they cannot be made to cut much deeper than one-half to three-quarters of an inch. If the packing and working has been well done, the moisture should be so close to the surface that such drilling will bring the seed in contact with it.

Work By Team: Those who do not have traction outfits may say this is all right for some farmers, but what can we do? Start early, plow as much as you can do the same day. Do not continue this process until you have the entire area you intend to seed to flax done before you commence to seed. Be satisfied to prepare the seed bed for from 10 to 20 acres, then sow. Start seeding just as early in the spring as you can without too much danger from frost. **Young flax will stand a rather heavy frost in the spring. It is better to have it frozen off twice in the spring than once in the fall.** After you have the first 10 or 20 acres seeded, prepare a similar area and do likewise.

Soil should not be worked when it is wet for that spoils its texture. It is, however, hardly possible to do so much work upon soil or sods when in good tillage as, by any chance, to make them too firm.

Types of Tools: There are many types of tools which are satisfactory. The stock raiser makes a success of raising a certain kind of stock because he has a liking for that particular kind. So it is with the man who undertakes to make a seed bed on sod. He makes a success because he understands or knows how to make use of the particular kind of tools which he is using. One principle, however, should be kept in mind; **do not cut up the sods or loosen the slices in any manner.** The purpose of all the steps is to cause the sods to lie flat.

Depths of Plowing: Plow as deep as can be done and yet have the slices mash flat. Three and a half to four inches on most types of soil is about right. If you have a light team, be sure not to cut more than can be properly turned down flat. In dragging, discing or harrowing, have the tools so set as not to stir the sod, but rather to work it flatter and form sufficient mulch to fill up the cracks and under sod spaces. When there is sufficient sub-soil moisture, shallow breaking properly handled to form a seed bed will very often give a good yield of flax. When there is sufficient power, we recommend the deeper plowing. Yet there is no object in plowing so as to turn up the light gravel in some of the lighter lands.

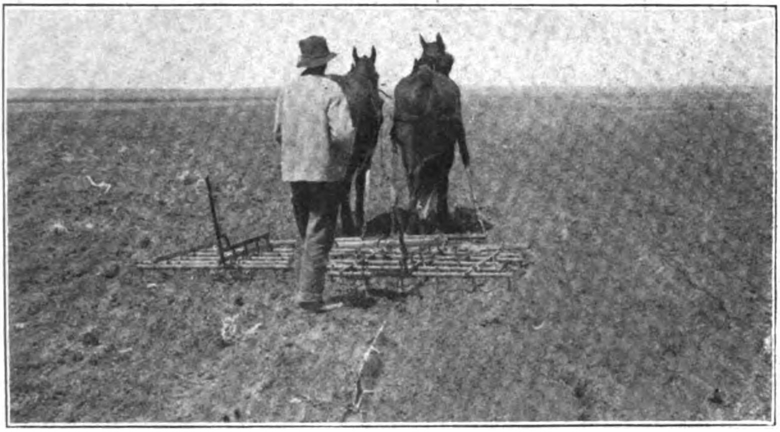

Fig. 17—Homesteader working down a thin tough sod with the harrow. If he harrows enough the cracks and air spaces get filled with a fine mulch of dirt which is a good substitute for packing. The team is also an aid to packing.

How To Determine Whether To Seed Immediately Following the Plowing in the Spring Or to Summer Work the Land for the Crop the Following Year: There are certain regions and certain types of soil in which sufficient moisture cannot be maintained to produce a crop if seeded immediately following the spring breaking. Such lands naturally fall under the "dry land" methods of agriculture, and summer tillage for storage and conservation of the moisture which falls is indicated. It has been proven by many dry land farmers in the drier regions of Montana and the drier regions of Northwest Dakota and British America that spring plowing of the sods lands, followed by careful summer tillage thruout the first season usually results in a crop of flax seed which pays abundantly for all the work done. There is only one drawback

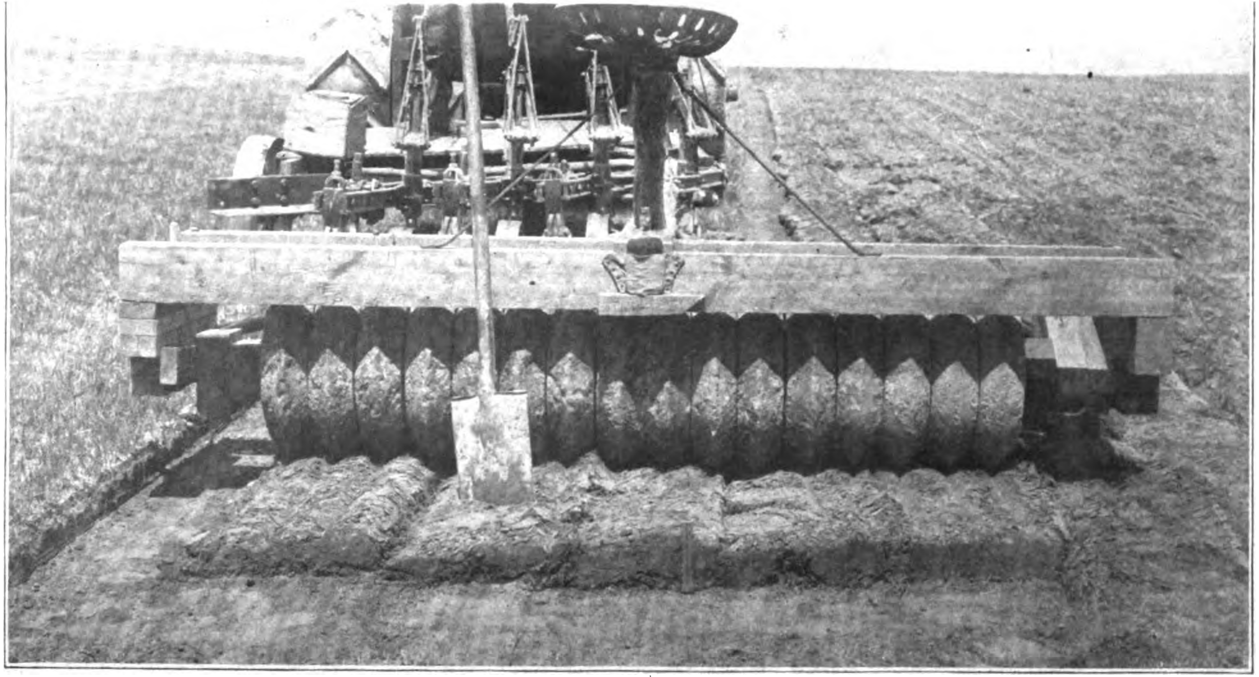

Fig. 18—Rear view of plowing and packing outfit. Notice the furrow slices, how the grass side fits down on the sub-soil. This is how sod lands should be packed for flax—or other crop.

and that is, if such summer worked lands chance to be surrounded by a weedy district, it is apt to become thoroughly filled with weed seeds by the drifting action of the winds. It may thus be necessary to guard against the weeds. Fig. 19 illustrates a good method of determining whether or not the sods may be spring seeded with fair chance of success. If, in a good, compact clay sub-soil or clay-like sub-soil, the moisture does not extend downward from two to two and one-half feet, it is too much of a gamble with nature to seed a crop on that particular piece of soil that spring. In certain exceptional summer seasons there may come heavy rains sufficient to continue the crop on to maturity. This is against probability. If the ground is not already pretty well supplied with moisture at seeding time, the crop is pretty certain to reach a condition when a few hot winds destroy the possibility of a pay yield. Late spring and summer rains, even tho' very heavy are found to wet down but a short distance and in a few hours of sun-

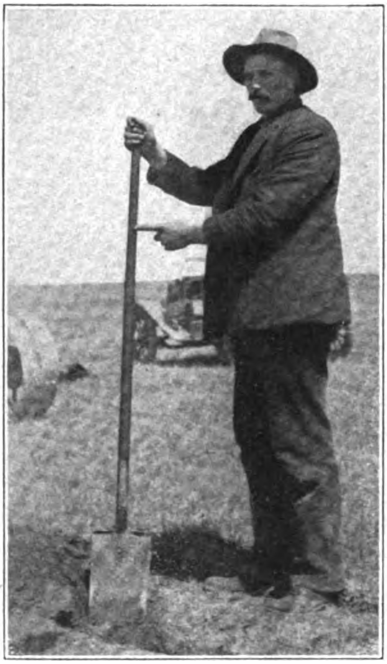

Fig. 19—This man is digging to learn how deep the moisture extends from top downward. This will tell him whether he should plow, pack, harrow and sow—or if he ought to summer cultivate, and prepare for crop the next year.

shine and wind the moisture is again thrown into the air. The crop is further damaged under such conditions by the tendency to cause it to produce its roots upon the surface so that when the hot winds dry out the surface the crop must blight, sicken and die.

Statistics and weather reports are good in their way, but they are more useful as agents for the sale of real estate than for determining whether a particular piece of lands does or does not have stored in it sufficient moisture to mature a crop.

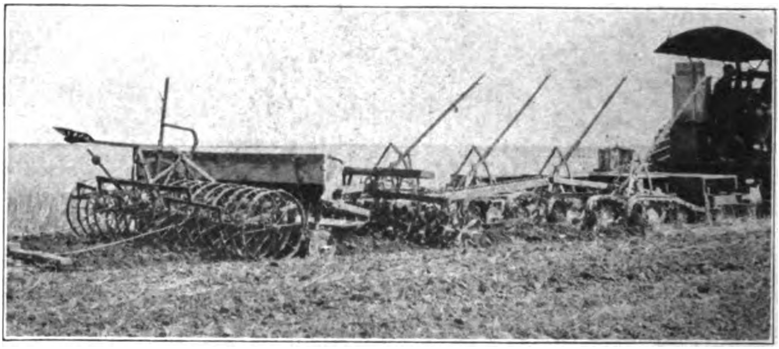

Fig. 20—All operations at once, plowing, packing, drilling and dragging or planking in tandem. This is best method of procedure when soil is in proper condition. The grain goes at once into a moist, firm seed-bed.

We think that each farmer can make soil moisture tests for himself in the spring which will be much more enlightening than the talk which one often hears about rainfall in inches. **The question is not whether there has been a rainfall of 15 or 16 inches during the year, but whether the sub-soil actually does or does not contain moisture sufficient to carry the crop to maturity.** If in a dry land region which year by year is naturally so classed, you had best make some tests for yourself.

The Time of Seeding: Sow Early. Each man must be his own guide and act according to the natural atmospheric environments of his own farm.

Liability to frost action varies in different localities of approximately similar regions. The region for which we are writing represents the high table lands or foot hills of the rocky mountains. When spring opens there is not again apt to be heavy frost action which will be likely to be destructive to the young flax. If, however, it is frozen off while it is quite young, only the seed is lost. The work necessary to seeding the ground again will only be that much improvement on that which has already been done. On the other hand, in the same regions, frost is liable to come early in August, and sometimes is very destructive. **Furthermore, the flax crop, when it is in blossom or when the seeds are not perfectly formed is very badly injured even by a comparatively light freeze.** Even tho' frost does not come in the fall in time to prevent maturity. If fall rains set in and cold nights come on, the crop tends to remain green and grows a lot of new seed pods so that there is no time when an evenly matured crop can be harvested. **Sow Early.**

Rate of Seeding: Under dry land conditions, or under semi-dry land conditions thin seeding should be the rule. If there is likely to be a shortage of moisture in the sub-soil at the time the grain is maturing, then the aim should be to have a comparatively few, sturdy, well rooted plants on the ground rather than many slender, weak, poorly rooted plants in competition with each other. The old rule of half a bushel of seed to the acre did fairly well in the wet regions, but even there is now found to be too much. The more common seeding is now one-third of a bushel per acre or less. On a properly prepared seed bed, in the regions for which this bulletin is written, not to exceed 12 to 14 pounds of seed should be sowed.

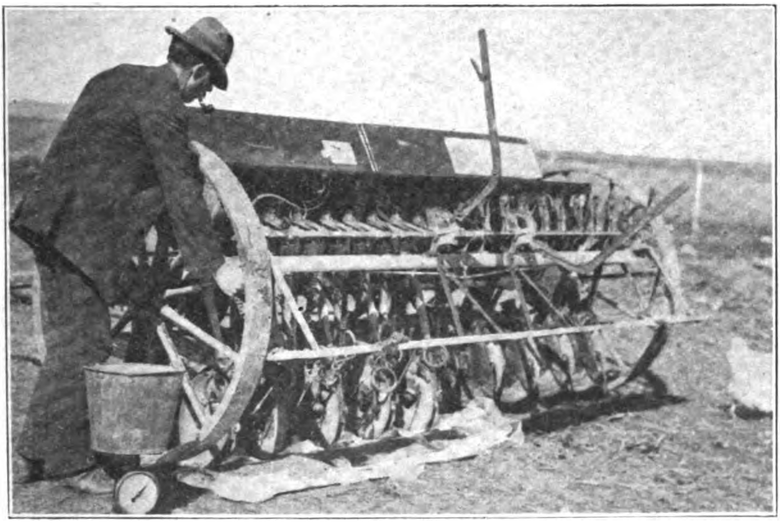

Fig. 21—Setting a drill and making a trial to learn how much it will sow per acre. This is very important to know. Any one can do it. No drill can be depended upon to do what the notches indicate. All flax seed samples are not alike.

Calibrating the Drill: It is usually supposed that any ordinary drill can be set to sow a given amount of seed. This is not the case. Drills of the same make vary greatly in this respect. Even the two sides of the same drill may sow at a different rate. The size of the seeds of the particular sample of grain determines how many pounds should be used per acre. It is well, therefore, to set the drill to do the particular piece of work which each man has to do. Adjusting the drills to do the exact amount of seeding is called calibration. There are 43,560 square feet in an acre. Divide this number by the number representing the width of the drill in feet. Divide the number thus obtained by the number of feet represented in the circumference of the wheel. This will give the number of revolutions which the wheel would make in drilling one acre of ground.

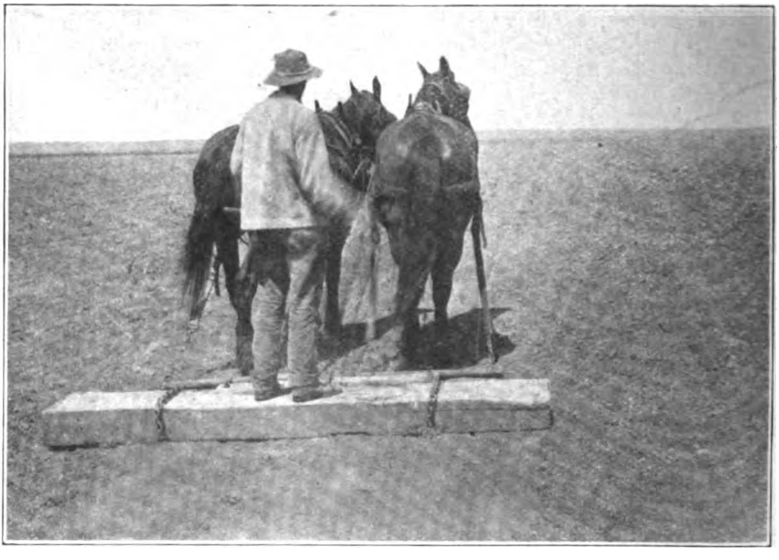

Fig. 22—Homesteader planking the ground to form an even seed bed. This will do most good if done immediately behind the drill.

Jack up the wheels and turn enough times to represent the distance which would be travelled in sowing one fourth of an acre. Collect the seed and weigh it. If it is too much or too little the drill should be readjusted until it will throw the amount of seed desired. If large areas of flax are to be seeded, it will be found that this method of testing out the drill will pay for itself in the seed saved, and a very great improvement in the evenness of the crop will be obtained.

A very efficient method of trying out the rate of seeding is to set the drill to sowing over a smooth roadway. Count the number of seeds which fall in a yard of distance which a shoe travels. This will tell rather accurately, approximately how many seeds are falling per inch. If the flax seed is good and the seed bed is properly prepared, one seed per each three fourths inch of distance will be enough. He who sows on an unprepared seed bed had best stay by the old rule of sowing approximately one half bushel to the acre.

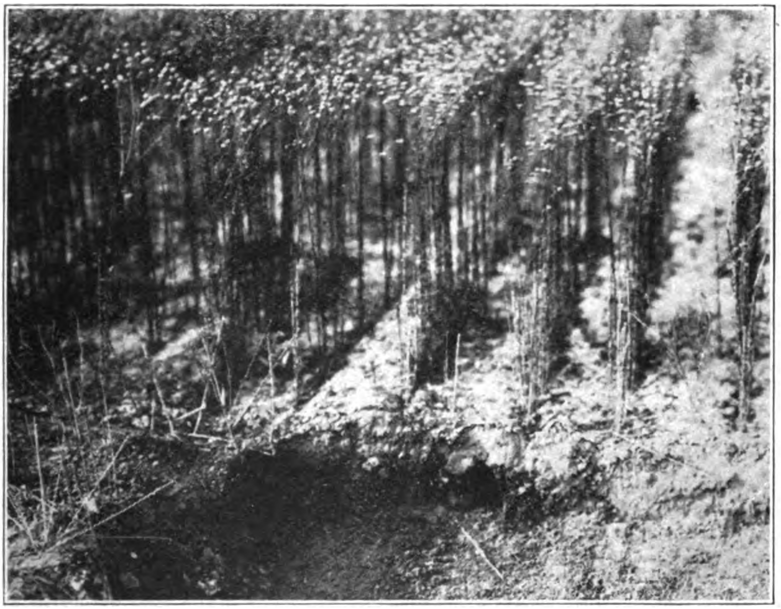

Fig. 23—Crop at maturity on new sod land which was rather perfectly packed and harrowed to form an even seed bed. This man could cut and save all heads because his seed bed was very even.

Planking: Many who have had success, have followed the system of planking after the drill. This is done even tho' the ground is well plowed, dragged, harrowed or disced and drilled. The planker usually consists of three or four heavy planks built together in the form of an old-fashioned stone boat in the manner characteristic of weather boarding. This is dragged behind the drill so that the over-lapping edges of the planks point backward. The action tends to pack down the fine dust particles, even up the ground, and cover seeds that

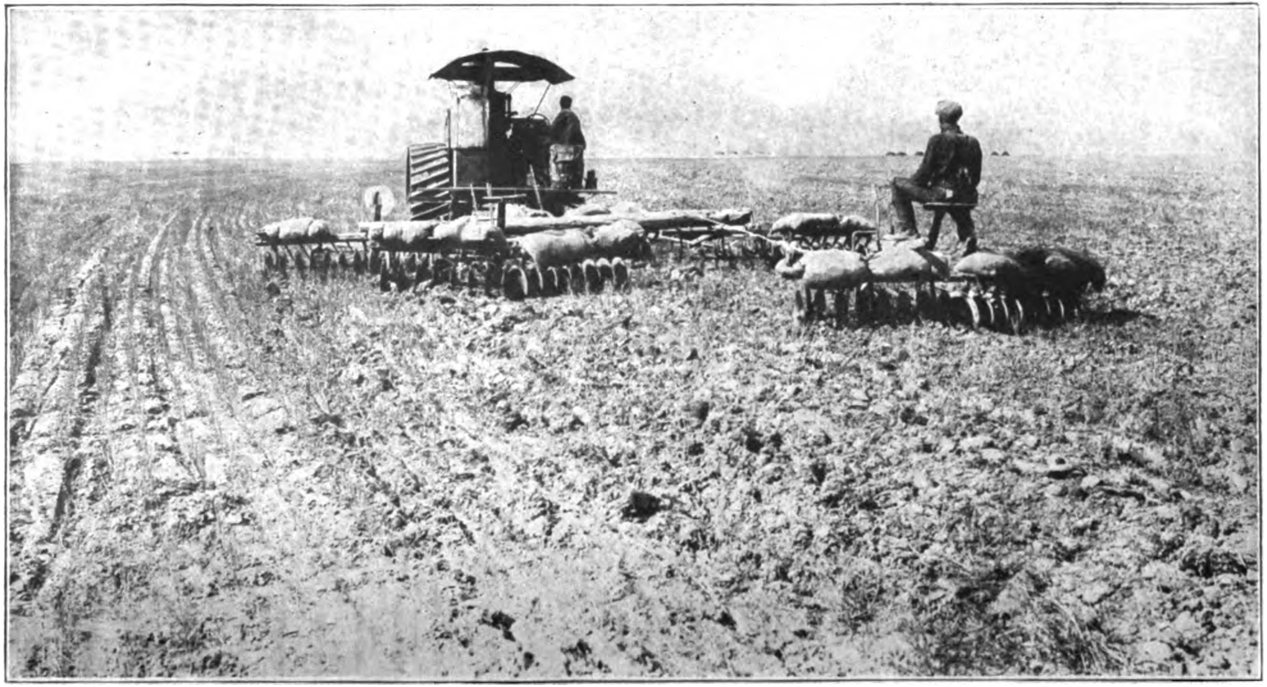

Fig. 24—Flax on sod is a fine preparatory crop for wheat or other cereal. As soon as cut, the stubble land, should be thoroly disked over. If a packer followed, it would pay for the work. Knock down the stubble or break them off. They pull moisture from the sub-soil.

might lie on the ridges uncovered. It also tends to firm the ground upon the seeds, and gives an opportunity for all of them to get an even start which tends to give even ripening. In the drier regions the old-fashioned press drill or press attachment will be found to give exceedingly fine results with flax. Any type of heavy plank or beam will tend to do the same kind of work. Fig. 22 illustrates how one homesteader prepared a very nice seed bed with a heavy beam.

It is not intended to carry the discussions of this bulletin beyond the finish of seeding operations. It may, however, be well to remember that the work done upon the preparation of the ground for this crop should not be lost and the proper crop should be seeded afterwards in order to make use of the conditions here provided.

Crop Rotation: So far as flax is concerned, crop rotation is an absolute necessity. In spite of all the care which may be taken with the seed with regard to the prevention of disease, some of the root and seed diseases of the crop will yet be introduced into the land. Some wilt-sick and canker-sick plants occur in every crop under the best conditions. The straw, stubble and roots from these wilt and canker-sick plants when plowed under will soon distribute the disease to large areas of ground. If the flax be put on the land the following year, the roots from the young plants, as soon as they come in contact

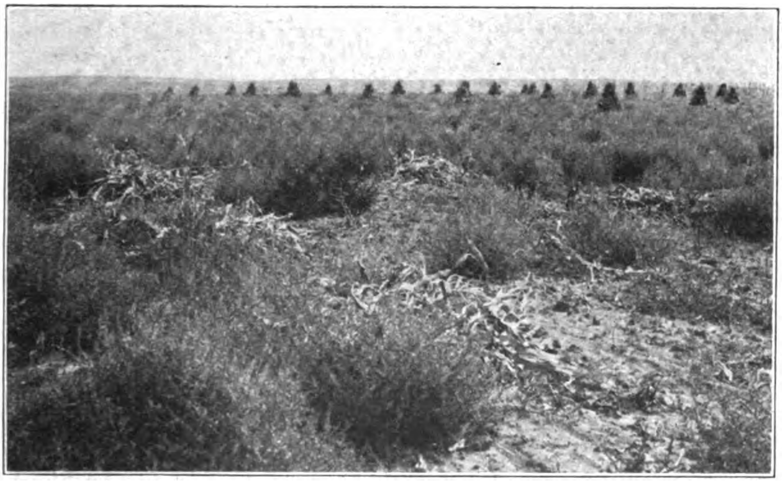

Fig. 25—Crop rotation is a necessity to proper agriculture. Corn is a splendid crop to preceed flax on old worked lands—but not with this sort of corn culture. It won't do.

with this old straw will become infected and thus the spread of the disease will be rapid. While the crop the second year may not fall off in yield to such extent as to cause alarm, the amount of disease which is introduced into the soil and seed is greatly increased, so that it takes a strenuous system of ground cleaning to purify the soil so that a pay crop of flax may again be produced there.

Summer Cultivation: This bulletin is written largely for those portions of the semi-dry regions in which the rainfall during the fall of the year, winter and spring months is sufficient to moisten the ground to such extent as to insure the crop provided reasonable method of soil preparation is done. There are many areas, however, in which the rainfall of a single season is not sufficient, nor can it be relied upon during the hot months. On such lands, proper summer cultivation can conserve the moisture and if properly done, deep tillage and consistent work will form just such sort of seed bed as is most desirable for flax. There are thus many parts of Montana and Western Dakota in which the regular methods of dry-land farming will be found to be most profitable, and even in those regions in which the rainfall is more certain, great success can be had by following this procedure. We would therefore, recommend that each farmer set aside twenty, thirty or forty acres each year to be prepared by surface tillage thru the summer. The method is especially applicable to all those regions in which the corn crop does not seem to be a success or for those farmers who have not as yet stock to make use of the forage. When corn can be grown, this crop may be used in place of fallow, after cereal crops. There are probably no large areas of lands in either state which can not be made productive of large crops under a system of alternate tillage and cropping.

Volunteer Flax: Where a previous first crop has shelled so that a good deal of seed is left on the ground, many farmers are inclined to sow flax there the second year because they think they will be able to procure the volunteer crop which comes. This is an error. If the seed bed is properly prepared the volunteer flax will practically all be destroyed. If not properly prepared, the volunteer flax will be mature many days before the seeded crop is ready. It is usually impossible to save the seeds from a volunteer crop and yet have a reasonably good yield from the new crop. In regions of sufficient sub-soil moisture, wheat is by far the best crop to follow on such lands, and the stubble should not be plowed. As soon as the flax is headed or taken off, the stubble should be disced, knocked down to prevent the upstanding stubble from acting as wicks to draw away moisture. First disc in direction of the furrow slices, afterwards in the diagonal or cross direction. On the last discing a clod crusher following the disc makes a fine improvement. The seed bed should essentially be prepared in the fall so that the wheat can be seeded at the earliest possible time after the snow leaves the ground in the spring. The volunteer flax, if any comes, will be saved in a wheat crop.

Flax After Corn: Careful experiments and the work of numerous farmers have shown that flax, after corn, without plowing the land, is apt to give one of the best possible yields.

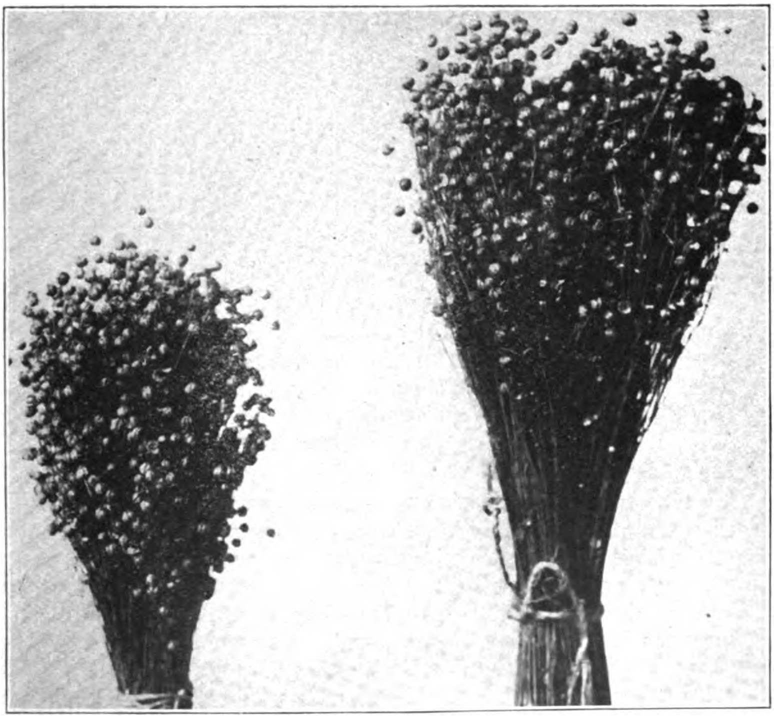

Fig. 26—Does it pay to summer work dry land areas for flax? It certainly does not pay to plant if there is not sufficient moisture in the subsoil. Good crops have been grown after bare summer cultivation in very dry regions. These two bundles show the contrast in one comparative trial. The larger bundle was grown after summer cultivation. The other was from an equal area spring worked.

It must not be cropped in the way which is indicated in Fig. 25. The average corn field, as cultivated in the west and northwest portions of our country is a nursery for weeds. If the corn is properly cultivated, and kept free from weeds, the the flax crop following will be clean. To prepare clean corn ground for seeding flax, level the same in the fall by the use of discs and heavy railroad irons or split log drags. In the spring, disc, harrow and pack thoroughly and seed early.

Irrigation: From a study of flax under irrigation both in Northwestern North Dakota and in various irrigation regions of Montana, it is evident that the crop is going to be one of the standard crops of the irrigated regions. It is too early to summarize final directions, regard proper amount of water and time of application. It is evident that the preparation of the seed bed will need to be even as thorough as in the case of the dry land farming. It will be of much importance that there should be proper deep plowing and an even surface, so the drainage may be complete on the surface. Flax, cannot thrive if water stands on the surface for any length of time, especially during hot weather. If seed production is the main aim it should be remembered that flax tends to continue to blossom as long as the supply of soil water is high, especially if the temperature is low. There should be a sufficient amount of moisture placed in the soil to maintain the crop thruout the growth season until near maturity. After boll formation the water supply should gradually become less and less until the crop is evenly ripened. **It is probable that the best results will be obtained by one thorough soaking of the ground either just preceding the seeding time or immediately following the time when the flax is about three or four inches high.** With most types of soil, under most conditions, it will not be found profitable to irrigate at any other later period, at least not later than the blossoming stage.

It should be remembered that wilt is most destructive under wet land conditions. Therefore, under irrigation, great care should be taken in seed selection and treatment that the soil may not become infected, for the flood waters of irrigation will readily carry the fungi which produces soil sickness from one area to another. Wet lands also remain flax-sick for a longer period of time than do the dry land or the semi-dry land areas, where the action of cultivation is more destructive to the parasites.

Finally: To preserve the new lands **from becoming flax-tired or flax-sick, the farmer should cut his crop when it is dry, thresh it when it is dry, and never allow the seed to become mouldy or damp if it can possibly be helped.** It will be wise to discontinue the process of throwing loose bunches on the ground to remain there an indefinite time subject to the action of rains and soil moisture. Under such conditions, the fungi, form their mould like threads thru the straw of the dampened bundles and gradually infect all seeds. They also produce great masses of spores which are scattered by the wind and washed water to large adjacent areas. In all cases in which the flax is long enough to be tied by a binder, that is the most satisfactory method. If the header is used, the grain should be thoroughly ripe so that the headed straw can be taken immediately to stacks as shown in our Fig. 27 that the threshing may be done at the earliest possible date.

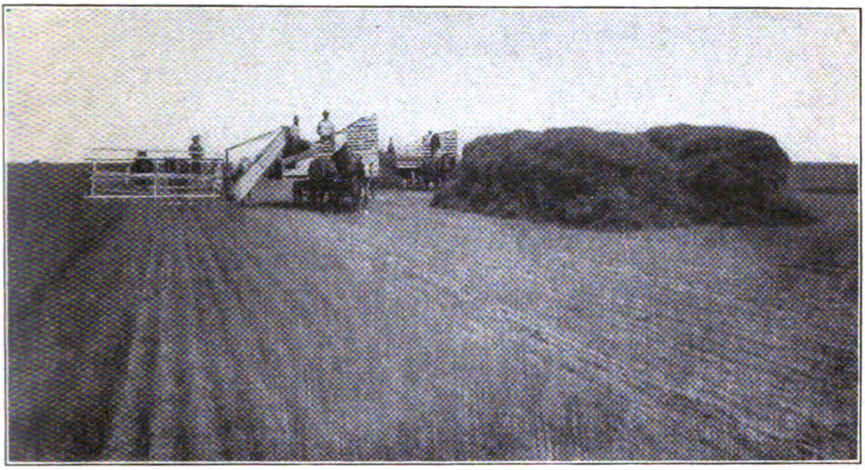

Fig. 27—The header and this sort of stacks will save day mature flax from snow over winter.

Wet flax, and mouldy seed **means deteriorated seed, rapid crop deterioration and flax-sick soil.**

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North Dakota Agricultural College

Government Agricultural
North Dakota
Experiment Station

OF

NORTH DAKOTA

BULLETIN NO. 104

Cost of Producing Farm Crops

BY

W. R. PORTER

Any farmer, teacher or student in the State may have this bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA, U. S. A.
APRIL 1913

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FOREWORD

In presenting this bulletin covering costs and economies of production as recorded upon the North Dakota Experiment Station Demonstration Farms it will be noted that the factors of cost are charged upon the basis of the experiments made by the Minnesota Experiment Station and the United States Department of Agriculture in cooperative experiments in our neighboring state of Minnesota. These factors of cost should closely approximate those for North Dakota and as a liberal factor of safety is adopted I consider the results dependable and practical.

It must be remembered, however, that careful work and intelligent business methods must be adopted by the farmer who uses the cropping plans and cultural methods reported herein, if his result correspond. For example, the feeding value of corn fodder and ensilage is as high in proportion to hay as it is calculated to be in this bulletin, but if the grower does not have marketable healthful live stock of some sort coming on that will convert these forage crops into saleable products he may grow these crops at a loss as nothing to correspond to the grain elevator will be at hand to pay him a reasonable price for the raw material The shipping and handling charge is high on all rough provender and it deteriorates so rapidly after the immediate season in which it is grown that it must be classed as a near perishable commodity.

If the farmer proposes to feed some of his corn to pigs the size of litter he produces per sow is a feature of importance in placing the balance on the right side of the ledger. The items that determine whether large or small litters will be produced depends upon the handling of the sows for the six or eight months before the pigs are born as well as to the care at the time of farrowing, for neglect at the latter season may result in no shotes to put into the feed lot when the corn is ready to manufacture into pork. Buying young stock to feed has more disadvantages than that of its cost, as the buyer will in many cases be getting poorer blood and culled out, unthrifty individuals.

The manufacture of forage and unmarketable grain crops into live stock products requires some business acumen and ability. Buying at a bargain helps increase the profits while making a bad bargain handicaps the entire crop. Neglecting a milk cow for only a few weeks either in the form of bad care or in poor food reduces the quantity of milk she will produce during all the remaining time of that milking period and represents a tremendous factory loss of your alfalfa and corn crops which she is to consume and transform into beef or butter.

This plan of farming does not lend itself to a short time tenure as special equipment in barns, yards and pastures are required and the necessary breeding stock must be at hand and carried along from year to year.

The caution given above need not alarm anyone but rather encourage him instead as it means more interesting and skillful work. The present prices and shortage in supply of live stock throughout the United States augers well for profit in the business for a number of years to come.

J. H. Shepperd.

Preface

The following farmers have cooperated with the North Dakota Experiment Station in conducting demonstration farms during the years 1906 to 1912. For their faithful work the thanks of the Agricultural Department of the North Dakota Experiment Station and of the author are due and hereby tendered:—C. E. Barber and David Steiner, Beach, Billings Co.; John Christiansen, New Salem, Morton Co.; Joseph Hare, N. F. Boucher and F. O. Hellstrom, Bismarck, Burleigh Co.; R. H. McEnany and John Meiers, Ross, Montraile Co.; C. A. Stubbins, Granville, McHenry Co.; Chas. Pettes and Fred Keitzman, Lakota, Nelson Co.; M. P. R. Strandskov and C. C. Sorenson, Flaxton, Burke Co.; Thomas McCreary, Carrington, Foster Co.; J. F. Jaberg, Sanborn, Barnes Co.;; Eastgate Bros., Larimore, Grand Forks Co.; John T. Flack, Page and Thomas Punton, Ayr, Cass Co.; Alex Morrison, Bathgate, Pembina Co.; Fred Wilhelm, Jamestown, Stutsman Co.; Walter Peterson and Anton Peterson, Washburn, McLean Co.; S. E. Kurtz and Sons, Hazelton, Emmons Co.; Peter Traynor and Edwin Traynor, Starkweather, Ramsey Co.; O. H. Dolve, Portland Jc., Trail Co.; Wm. P. Cairncross, Wahpeton, Richland Co.; Th. T. Kristjanson and Martin Reinholt, McLeod, Ransom Co.; Eilif Lavik and Sons, Rugby, Pierce Co;. Allen Hoople, Hoople, Walsh Co.; Chas. Roberts, Dawson, Kidder Co.; John Southam, Mohall, Renville Co.; L. W. Beckwith, Oakes, Dickey Co.; George Kline, Mott, Hettinger County.

The writer acknowledges the valuable work of former Superintendent E. G. Schollander and Assistant Superintendents M. B. Johnson and E. W. Hall in the planning and supervising of the field operations on the state demonstration farms.

Assistance and suggestions in reviewing and editing this work by Professor G. W. Randlett, Vice Director J. H. Shepperd and Director J. H. Worst is acknowledged.

The writer has based the value of labor and machinery on the figures published in Bulletin No. 117 of the University of Minnesota and to that work much of the data in this bulletin is credited. W. R. Porter.

Farm Profits Result from Systematic Crop Rotation

The North Dakota State Demonstration Farms were established by and under the jurisdiction of the North Dakota Experiment Station in the spring of 1906 with funds supplied by the Northern Pacific and Great Northern railroads. These farms were located at Beach, New Salem and Bismarck on the Northern Pacific and at Lakota, Granville and Ross on the Great Northern. There farms were taken over entirely by the Station in the spring of 1907 as the Legislative Assembly of that winter provided funds to·operate these farms, besides six additional ones, which were located that spring at Flaxton, Carrington, Sanborn, Page, Larimore and Bathgate. The Legislative Assembly of 1909 provided for twelve additional farms nine of which were located in the spring of 1909, at Jamestown, Hazelton, Washburn, Wahpeton, Portland Jc., Hoople, Starkweather, Rugby and McLeod. In the spring of 1910 three more farms were established at Oakes, Mohall and Dawson respectively. In the spring of 1911 the farms at Ross and Flaxton were discontinued and new farms immediately established at these points. In the spring of 1912 the original farms at Lakota and Page were discontinued but were replaced by adding two other farms at Bartlett and Ayr, respectively. A farm was also conducted at Mott in 1912 with funds which the Northern Pacific Railway company furnished.

The oldest of these demonstration farms has now been operated for seven years. In all there have been six hundred nineteen fields of grain, hay and corn produced in systematic rotation.

The time is yet too short and the number of farms are too limited in number to make certain what results may be expected from them but they indicate what may be done with good seed, a good rotation and good tillage in North Dakota.

No attempt has been made to get high yields by selecting extraordinary land or by locating the farms in exceptionally good sections of the state. In all cases land that is typical of the respective farming communities was chosen. In some cases it may be a little better than the average; in other cases, it is poorer than the average land. As far as can be ascertained, the average demonstration farm soil is no better than the average tillable soil of the state.

The farmers chosen to manage these farms are better than the average farmers of the state and they have on the average more sapital and better machinery than the average farmer. However, no special machinery is used on these farms, whatever machinery the manager has for his own use is used. A record of all field operations has been kept since the farms were located by the Station. At no time has there been more work put on these farms than will pay dividends. One field is manured every fifth or sixth year and about the same amount of organic material is returned to the soil that is removed in each crop, provided all the straw, hay, cornfodder etc., were fed on the farm and the manure so produced returned. No commercial fertilizers have been used on these farms because trials with fertilizers on small grains at both the North Dakota and Minnesota Experiment Stations have shown an actual loss in net profit where the fertilizers have been purchased and applied as compared with similar land and crops where no fertilizers were used. In the past no fertilizers have been applied to potato land but they would in all probability pay well if so applied and some trials of this kind will be instituted next year. The plan followed in the operation of these farms has been outlined to show what good seed, good cultivation and good rotation will do on average North Dakota land when ordinary farm machinery and equipment are made use of by actual farmers who are making a living from the farm. No more work than the ordinary farmer can accomplish in the average season has been put on the lands. At all times these farms have been conducted with the idea of making the largest possible net profit per acre with a reasonable amount of timely labor and they have never been operated with the idea of getting the largest possible yields per acre, regardless of expense.

COST OF PRODUCTION AND HOW IT IS ESTIMATED ON THE NORTH DAKOTA STATE DEMONSTRATION FARMS.

In order to know whether the farm operations are paying or not, it is necessary to know the cost of production. The most reliable figures available are those published in Bulletin No. 117 of the University of Minnesota. The farms at Halstad, Minn., where the data on farm labor, horse labor and the depreciation of farm machinery was gathered from 1902 to 1907, is in the Red River Valley, about forty miles north of Fargo and is strictly comparable with North Dakota conditions. Labor, since 1907, has been increasing in cost to quite an extent. The cost of monthly labor at Halstad from 1905 to 1907 inclusive was equal to 11.79 cents per hour; April 1st. to October 31st. inclusive (See Minn. Bul. No. 117, p. 12.) and day labor cost was as follows:——April, 13.68c; May, 12.84c; June, 16.90c; July, 15.28c; August, 22.05c; September, 23.76c and October 24.76c per hour, respectively (See Minn. Bul. No. 117 p. 13) or, an average of 18.46 cents per hour per man—56 1-2% higher on the average than monthly labor during the same period. The figures for day labor at Halstad are used for all field operations in this bulletin and they should be sufficiently high to offset any advance in wages that may have occured since that period. The horse labor is figured at 8.36c per hour on all operations in this bulletin. This is the cost of horse labor at Marshall, Minn. (Minn. Bul. No. 117 p. 16) and is 14 per cent higher than that found at Halstad, Minn. This figure should be higher than horse labor under North Dakota conditions. The average day's work for a man at Halstad from April 1st. to October 31st. inclusive is nine hours, two minutes. (Minn. Bul. No. 117, p. 53.) All the field operations on the demonstration farms are done between April 1st. and October 31st. inclusive or, if some work is occassionally done during the last days of March or early in November, it is figured in the April or October wage rate per hour. A seeder of 22 shoes (11 feet) is figured as doing full capacity work traveling at the rate of two miles per hour. A corn planter is figured as doing full capacity work at a speed of one and one-half miles per hour. A plow is figured as a fourteen inch gang doing full capacity work at two miles per hour. A harrow is figured to lap two feet; a disc, six inches; binders and mowers are figured to run six inches short of full capacity; subsurface packers, rollers and cultivators are figured full capacity. All machines, except corn planters, are figured as traveling at the rate of two miles per hour. Machine cost is calculated the same as that consumed annually on the average of all the Minnesota farms (Minn. Bul. No. 117, p. 18.) which is considerably higher than at Halstad the point most comparable with North Dakota conditions. This is figured as the total value of the machine consumed per acre and is as follows:

For binders	$ .186
For drills	$ .171
For Corn binders	$ .826
For Corn planters	$ .087
For mowers	$ .206
For rakes	$ .085
For plows	$ .087
For harrows	$ .017
For discs	$ .089

The cost of hauling manure is estimated at $ .311 per load this being the average cost of hauling a three horse spreader load in Minnesota (See Minn. Bul. No. 117, p. 25). In this bulletin no value is placed on the manure beyond the labor of horses, men and the machinery cost.

Manure was probably one of the factors that have caused the net profits obtained on these farms. In North Dakota Bulletin No. 100, page 32 these lines occur, "In these experiments the increase due to farm manure was 1.24 bushels the first year after the manuring, 2.89 bushels the second year after, 3.90 bushels the third year. The total increase was 8.11 bushels or 11.2%. Each load of manure produced 1.35 bu. of wheat. The beneficial effects of such manuring extended over a longer period than the effects of corn in the rotation."

On page 41 of the same bulletin, the value of manure is calculated for corn, millet and the three succeeding wheat crops as follows: "There are two plots in Series I which show the effect of farm manure applied once in a four year cropping system. As an average manure has produced an increase in the yield of all crops on each of these plots. Using the data in table IV as a basis for calculation each load of manure has been worth $1.07 when applied to corn in rotation with wheat on plot 6, and $1.04 when applied to millet in rotation with wheat on Plot 10. However, it must be noted that these values are based on prices of farm products when they were much lower than at present. If we use the average farm price, December first for the five year period, 1906-10, we find each load of manure on plot 6 has produced an increase of $1.40 worth of products and on 10 each load has produced an increase of $1.65 worth. The increase produced by the manure has been much greater during the last two courses than the first two as will be noted from the data in the table below. The most satisfactory method of calculating this increase is on the percentage basis. The Increase in Wheat Yield Due to Farm Manure by Courses 1892-1906.

	Manure	Per Cent Increase			
Plot	Applied to	1st Course	2nd Course	3rd Course	4th Course
6	corn	5.5	9.3	21.5	12.5*
10	millet	6.1	10.1	33.0	30.2*

*Three year period only.

The land at New Salem and Bathgate has been approximately as long in cultivation as that on the Main Station at Fargo. Consequently, the increase yield due to manure would correspond to the third and fourth Courses. While general farm practice and the above figures show that manure is unquestionably worth more than the labor to haul it, it has no market value in this state, therefore, it is not considered of any more value than what it costs to apply it to the land. The item of general expense is probably large enough to partly cover the application of manure but it is not so figured in this bulletin; the cost of the application of manure is charged directly to the cost of the field to which it is applied for that particular year whether it is applied in the spring or in the fall. For instance, at Bathgate, oat land is manured in the fall and the following year it is put into corn; the entire cost of applying the manure falls on the oat crop which receives no direct benefit from the manure until the rotation begins again 6 years later or until the second rotation cycle begins. The cost of applying manure at Bathgate and on all farms with a six year rotation is equal to $ .518 per acre per year and at New Salem and farms having a five year rotation it is equal to $ .622 cents per acre per year when ten loads of manure are applied per acre once during each rotation cycle. The fact that the entire cost of applying manure at Bathate falls on the oat crop will reduce the net profit of that crop $2.59 an acre and will increase the net profit of each of the other crops $ .518 per acre per year. At New Salem the manure was applied at different times and to different crops so that the cost is more uniformly distributed among the different crops than at Bathgate.

The cost of twine is estimated as it is not known exactly how much twine was used to cut each field. A liberal estimate was allowed and the price was fixed as near that prevailing in the local market for each season as possible. In some cases, it may be too high and, in others, it may be too low but on the average it is approximately correct.

Threshing is figured at the rate of five cents per bushel of 32 pounds of oats; barley at the rate of six cents per 48 pounds and wheat at the rate of ten cents per bushel of sixty pounds which is probably about the average for the state.

Shocking is figured at a specified rate per acre; wheat costs $ .135 per acre (Halstad, Minn. Bul. No. 117, p. 45); oats, $ .152 per acre (Halstad, Minn. Bul. No. 117, p. 40); Barley, $ .156 per acre (Halstad, Minn. Bul. No. 117, p. 24); rye is figured at the same rate as wheat since there is no reliable data on the cost of shocking rye. Corn is figured at $ .400, the average of shocking corn at several Minnesota points (Bul. No. 117, pp. 25-30, Incl.).

There are several operations carried out on the farm which cannot be charged to any one project or field operation. In Minnesota (Bull.No.117, p.22) these items which are classed as general expense, are figured as $ .90 per acre, except at New Salem during 1910 a year when the crop was almost a failure it is figured at $ .80 per acre.

LAND RENTAL is an item of cost which is figured in as an legitimate charge because the value of the farm if invested as capital, would bring in income equivalent to 6 per cent. The farm as invested capital should yield this income, and the same should be charged as an expense in the production of farm crops. In this bulletin, interest has been charged at the rate of 6 per cent on the actual value of the land.

Three items of cost are omitted in this bulletin. They are 1st, The cost of hauling produce to market; Roads differ so much in condition, and the distance to haul is so different from that of an average farmer that it was considered best to omit this item of cost. 2nd, picking corn. In North Dakota there is no data accurate enough for use, and Minnesota data does not apply here since North Dakota corn is much smaller on the average than Minnesota Corn. 3rd, Taxes. An item that varies widely in different parts of the state and in different years. Taxes are probably never less than ten cents per acre, and they rarely exceed sixty cents per acre. These three items, viz: Cost of hauling, cost of picking corn and taxes are omitted on account of their variability, and the net profits discussed in this bulletin should be reduced the amount of the total of these three variable items.

PRICES OBTAINED FOR PRODUCE AND HOW ESTIMATED.

The prices used in this bulletin are as far as possible the local price for the same grade on December 1st each year. When such could not be obtained, the average farm price as given by the U. S. Department of Agriculture has been used. Practically all the prices of the small grains are local market prices on December 1st of the year in which they are grown, except in a few instances, like clover seed at Bathgate the value of which was figured on what the seed was actually sold for. The prices of hay, corn fodder, and corn stover have largely been estimated from the farm value as given in the United States Department of Agriculture report except in a few instances where the known actual selling price was used. Corn fodder was estimated as worth about three-fourths as much as timothy hay; stover at one-fourth and corn silage at one-third as In all cases the prices have been conservatively estimated: grain crops might have been sold at a higher figure, and the feed crop if fed to animals on the farm, should yield a higher value than shown in the figures in this bulletin with correspondingly enhanced net profits from the farm operations. In actual farm practice a large amount of live stock would have to be kept to consume the roughage produced, and to supply the manure to carry on farm rotations such as are used at New Salem and Bathgate. The price of seed wheat, oats, barley etc. is estimated at the December 1st price with about 10 per cent off for shrinkage, cleaning expense and cost of carrying it over winter. The cost of seed corn, peas, clover, timothy etc. is the actual price this seed cost as shown by the bills paid for the past six years.

NET PROFIT AT NEW SALEM. New Salem is one of the original farms put in operation. It has a record of seven years and is typical of a large area in the "Missouri Slope" country. This farm has had five paying crops, and two crops which did not pay expenses; the drought of 1910 was particularly severe, and in 1911 the soil drifted badly in the early spring, while dashing rains followed early in June. Following the rain came a period of drought. New Salem cannot therefore be said to have had better than the normal weather conditions. Of the six original farms, but four have a record of seven years, Ross and Lakota having been discontinued in 1910 and 1911 respectively. Beach has the best record of any of these farms, while Bismarck and Granville both located on sandy soils much lighter than the average of the Western part of the state, cannot show as satisfactory a net profit as the average soil would show. Below is a table taken from the Third Annual Report of the State Demonstration Farms of 1909 made by the Chemical Department of the Station and former Superintendent of Demonstration Farms Mr. E. G. Schollander.

	Moisture	Volatile Matter	Insoluble Residue	Ferric Oxide Fe202	Alumina Al203	Lime Ca0	Magnesia Mg0	Potash K20	Soda Na20	Phosphoric Acid P205	Sulfuric Acid, S03	Total	Nitrogen	Humus
Bathgate...	3.316	10.853	71.63	3.506	6.376	1.321	1.191	.697	.294	.1675	.099	99.5428	.3781	8.278
Sanborn....	2.367	9.877	77.337	2.750	4.065	.967	.899	.557	.410	1.70	.0037	99.405	.3625	7.090
Flaxton.....	1.860	8.942	79.792	2.890	4.060	.541	.632	.536	.351	.162	.0275	99.794	.331	6.170
Carrington..	1.758	6.583	82.976	3.360	3.510	.798	.736	.494	.237	.0926	.020	99.566	.2566	4.445
Larimore...	1.440	5.736	86.252	2.176	2.276	.604	.454	.353	.280	.1372	.0234	99.729	.2252	2.358
Page........	2.316	8.870	78.888	2.750	4.078	.886	.794	.477	.333	.2296	.0488	99.641	.3182	3.932
Lakota......	....	....	78.14	....	....	2.38	...	.29	.46	.13	....	....	.34	2.95
Granville....	....	....	89.03	....	....	.49	...	.21	.52	.08	....	.....	.21	2.18
Ross........	....	....	77.21	....	....	.94	...	.33	.82	.13	....	....	.34	3.14
Beach.......	....	....	78.75	....	....	1.70	...	.33	.77	.13	....	.....	.29	2.40
New Salem.	....	....	84.41	....	....	1.70	...	.27	.34	.10	....	.....	.21	2.22
Bismarck....	....	....	88.27	....	....	.58	...	.26	.42	.12	....	.....	.15	1.34
Average.....	....	....	81.057	....	....	1.076	...	.400	.436	.137	....	.....	.284	3.875
Average of 200 fertile soils....		7.06	79.95	2.68	5.20	2.16	0.55	.29	.25	.24	.03	99.47	.29	8.85

This shows that the New Salem farm is comparatively low in nitrogen phosphoric acid, potash, lime and humus as compared with Lakota, Ross and Beach, and that it is considerable ahead of Bismarck and Granville. These farms are all very much behind Professor Synder's (Minn.) analysis of 200 fertile soils in all the essentials of plant food. This farm also has been in continuous cultivation since 1885, which should cause profits to be considerable less than new lands would yield with similar methods of culture.

Below are seven tables showing the crops grown, the expense items and cost of each, in the production of the crops together with the total expense of production, the yields, market price, total income and total net profit or loss for each field on the New Salem farm for the years 1906 to 1912 inclusive.

TABLE I—NEWSALEM 1906

		No. 1 Corn		No. 2 Mac. Wheat		No. 3 Fife Wheat		No. 4 Oats & Peas		No. 5 Oats	
		Corn ⅛ bu. at $3.00	$1.50	M. Wheat 7 bu. at $ .60	$4.20	F. Wheat 6 bu. at		Oats $1.20 Peas		Oats 6 bu. at $ .30	
Seed			$1.500		$ 4.200	$ .80	$4.80	$10.00	$11.20		$1.80
Treating Seed	Chemicals			.087		.075				.075	
	Treating			.038		.033				.033	
	Machine cost			.040	.165	.040	.148			.040	.148
Seeding	Man labor	.403		.205		.205		.192		.192	
	Horse labor	.525		.501		.501		.501		.501	
	Machine cost	.348	1.276	.300	1.006	.300	1.006	.300	.993	.300	.995
Plowing	Man labor	.907		2.717		2.717		2.647		2.647	
	Horse labor	2.364		4.729		4.729		4.729		4.729	
	Machine cost	.348	3.619	.348	7.794	.348	7.794	.348	7.724	.348	7.724
Dragging	Man labor	.426		.373		.373		.354		.361	
	Horse labor	.959		.959		.959		.719		.719	
	Machine cost	.068	1.453	.068	1.400	.068	1.400	.068	1.141	.068	1.148
Cultivating	Man labor	4.627									
	Horse labor	4.728									
	Machine cost	.620	9.975								
Cutting	Man labor	1.167		.485		.485		.504		.485	
	Horse labor	1.182		.735		.735		.551		.735	
	Twine	1.280		.800		1.000				1.000	
	Machine cost	3.304	6.933	.724	2.744	.724	2.944	.824	1.879	.724	2.944
Shocking	Labor		1.600		.540		.540		.600		.604

Raking	Man Labor							.252			
	Horse labor							.276			
	Machine cost							.340	.868		
Stacking	Man labor										
	Horse labor										
	Machine cost		3.876						3.876		
Threshing	Cost per bu.			.100	11.400	.100	6.500			.050	7.700
Manuring	Man Labor										
	Horse labor										
	Manure						12.440				
	Machine cost										
General Expense			3.600		3.600		3.600		3.600		3.600
Land Rental			.900		.900		.900		.900		.900
Total Expense per plot			34.732		33.749		42.072		32.781		27.561
		3625 lb.									
		stover									
Yield per acre		29.700		28.500		16.250		4000 lb		39.500	
			14498								
			lb.								
			stover								
			118.800		114,000		65.000		16,000		158.000
Yield per plot			s. c.						lb		
	Per ton	1.500						6.000			
Value of product	Per bu.	.390		.500		.650				.350	
Value of crop			57.205		57.000		42.250		48.000		55.300
Total profit or loss per acre			5.618		5.812		.044		3.805		6.934
Total profit or loss on farm			22.473		23.251		.178		15.219		27.739

Total net profit—$88.86. Gross income per acre—$12.988. Cost per acre—$8.545. Net profit per acre—$4.443

TABLE II—NEW SALEM 1907

		No. 1 Fife		No. 2 Oats		No. 3 Oats & Peas		No. 4 Mac. Wheat		No. 5 Corn	
	....	....	....	....	....						
Seed		6 bu. Wheat at $ .710	$4.260	8 bu. Oats at $. 30	$2.400	6 bu. Oats $1.80 5 bu. Peas $7.50	$9.30	7 bu. Wheat $3.85	$3.85	½ bu. Corn $1.50	$1.50
Treating Seed	Chemicals ..	.075	....	.100	....	....	....	.087	....	....	....
	Treating ...	.033	....	.045	....	....	....	.039	....	....	....
	Machine cost	.040	.148	.040	.185	....	....	.040	....	....	....
Seeding	Man labor..	.205	....	.205	....	.205	....	.205	.166	.403	....
	Horse labor.	.501	....	.501	....	.501	....	.501	....	.525	....
	Machine cost	.300	1.006	.300	1.006	.300	1.006	.300	1.006	.348	1.276
Plowing	Man labor..	1.680	....	1.680	....	1.680	....	1.680	....	....	....
	Horse labor.	2.364	....	2.364	....	2.955	....	2.364	....	....	....
	Machine cost	.348	4.392	.348	4.392	.348	4.983	.348	4.392	....	....
Dragging	Man labor..	.098	....	.098	....	.098	....	.098	....	.294	....
	Horse labor.	.239	....	.239	....	.239	....	.239	....	.719	....
	Machine cost	.068	.405	.068	.405	.068	.405	.068	.405	.068	1.081
Discing	Man labor..	.301	....	.301	....	.301	....	.301	....	.301	....
	Horse labor.	.735	....	.735	....	.735	....	.735	....	.735	....
	Machine cost	.356	1.392	.356	1.392	.356	1.392	.356	1.392	.356	1.392
Cultivating	Man labor...	....	....	....	....	....	....	....	....	2.918	....
	Horse labor.	....	....	....	....	....	....	....	....	3.152	....
	Machine cost	....	....	....	....	....	....	....	....	.620	6.690

Cutting	Man labor	.485		.485		.504		.485		1.039	
	Horse labor	.735		.735		.551		.735		1.182	
	Twine	.480		.640				.480		1.280	
	Machine cost	.724	2.424	.724	2.584	.824	1.879	.724	2.424	3.304	6.805
Hand Hoed										10 hrs.	1.528
Shocking	Labor		.540		.604		.600		.540		1.609
Raking	Man labor					.363					
	Horse labor					.275					
	Machine cost					.340	.978				
Stacking	Man labor										Cost of
	Horse labor										hauling
	Machine cost						3.876			3.876	3.876
Threshing	Cost per bu.	.100	4.600	.050	4.000						
Manuring	Man labor										
	Horse labor										
	Manure		12.440								
	Machine cost										
General Expense			3.600		3.600		3.600		3.600		3.600
Land Rental			.900		.900		.300		.900		.900
Total expense per plot			36.107		21.468		28.919		22.475		30.248
Yield per acre		11.500		20.000		2500		9.500		6500	
Yield per plot			46 bu.		80. bu.	lbs.	10,000		38.000	lbs	26,000
Value of product	Per ton					6.000	lbs.			4.000	lbs.
	Per bu.	.860		.430				.660			
Value of Crop			39.560		34.400		30.000		25.080		52.000
Total profit or loss on farm			3.453		3.233		1.081		2.605		21.752
Total profit or loss per acre			.863		12.932		.270		.651		5.438

Total net profits—$41.823. Gross income per acre—9.052. Cost per acre—$6.961. Net profit per acre—$2.091.

TABLE III—NEW SALEM 1908

		No. 1 Oats		No. 2 Oats & Peas		No. 3 Mac. Wheat		No. 4 Corn		No. 5 Fife Wheat	
		8 bu. Wheat at $ .50		6 bu. Oats $3.00 5 bu. Peas		7 bu. at $ .80		½ bu. at $1.50		6 bu. at $ .95	
Seed			$4.000	$7.500	$10.500		$5.600		$1.500		$5.700
Treating	Chemicals	.100				.087				.075	
	Treating	.045				.039				.033	
	Machine cost	.040				.040	.166			.040	
			.185								.148
Seeding	Man labor	.205		.205		.205		.403		.205	
	Horse labor	.501		.501		.501		.525		.501	
	Machine cost	.300	1.006	.300	1.006	.300	1.006	.348	1.276	.300	1.006
Plowing	Man labor			1.750		1.750				1.750	
	Horse labor			2.364		2.364				2.364	
	Machine cost			.348	4.462	.348	4.462			.348	4.462
Dragging	Man labor	.098		.196		.196		.645		.196	
	Horse labor	.239		.479		.479		1.438		479	
	Machine cost	.068	.405	.068	.743	.068	.743	.068	2.151	.068	.743
Discing	Man labor			.356				1.087		.602	
	Horse labor			.735				2.206		1.471	
	Machine cost			.356	1.447			.356	3.649	.356	2.429
								10 hrs.			
Hand hoed									1.528		
Cultivating	Man labor							2.956			
	Horse labor							3.152			
	Machine cost							.620	6.728		

Cutting	Man Labor	.485		.504		.485		1.120		.485	
	Horse labor	.735		.551		.735		1.182		.735	
	Twine	.640				.640		.960		.640	
	Machine cost	.724	2.584	.824	1.879	.724	2.584	2.304	5.566	.724	2.584
Shocking	Labor		.604		.600		.540		1.600		.540
Raking	Man labor			.252							
	Horse labor			.275							
	Machine cost			.340	.867						
Stacking	Man labor										
	Horse labor				3.876				3.876		
	Machine cost										
Threshing	Cost per bu.	.050	3.800			.100	7.900			.100	8.200
General Expense			3.600		3.600		3.600		3.600		3.600
Land Rental			1.080		1.080		1.080		1.080		1.080
Total expense per plot			17.264		30.060		27.681		32.554		30.492
								2634 lb			
								stover			
Yield per acre		19.000		4250 lb		19.750		19.000		20.500	
								bu. S C			
									10,536		
									stover		
Yield per plot			76.000		17,000		79.000		76.000		82.000
					lbs.				S C		
Value of product	Per ton			6.000				1.500			
	Per bushel	.330				.710		.600		.910	
Value of crop			25.080		51.000		56.090		53.496		74.620
Total profit or loss on farm			7.816		20.940		28.409		20.942		44.128
Total profit or loss per acre			1.954		5.235		7.102		5.235		11.032

Total net profits—$122.235. Gross income per acre—$13.014. Cost per acre—$6.902. Net profit per acre—$6.112.

TABLE IV—NEW SALEM 1909

		No. 1 Oats & Peas		No. 2 Mac. Wheat		No. 3 Corn		No. 4 Fife Wheat		No. 5 Oats	
		6 bu. Wheat $6.00 2 bu. Oats $ .80 6 bu. Peas $10.50		6 bu. Mac. Wheat $6.00 Clover $1.60		½ bu. Corn $1.50		5 bu. Wheat $6.25 Clover $1.60		8 bu. Oats $3.20 Clover $1.60	
Seed			$17.300		$7.600		$1.500		$7.850		$4.800
Treating Seed	Chemicals			.075				.062		.100	
	Treating			.033				.028		.045	
	Machine cost			.040	.148			.040	.130	.040	.185
Seeding	Man labor	.785		.435		.403		.455		.442	
	Horse labor	1.002		.501		.525		.501		.501	
	Machine cost	.300	2.087	.300	1.236	.348	1.276	.300	1.256	.300	1.243
Plowing	Man labor	.967		1.750				1.750		1.750	
	Horse labor	2.364		2.364				2.364		2.364	
	Machine cost	.348	3.679	.348	4.462			.348	4.462	.348	4.462
Dragging	Man labor	.190		.190		.564		.288		.190	
	Horse labor	.479		.479		1.439		.719		.479	
	Machine cost	.068	.737	.068	.737	.068	2.071	.068	1.075	.068	.737
Discing	Man labor	.485						.485			
	Horse labor	.735						.735			
	Machine cost	.356	1.576					.356	1.576		
Cultivating	Man labor					2.389					
	Horse labor					2.364					
	Machine cost					.620	5.373				
Hand hoed	Labor					10 hrs.					
							1.528				

Cutting	Man labor	.504		.485		1.120		.485		.485	
	Horse labor	.551		.735		1.182		.735		.735	
	Twine			.800		1.280		.800		.800	
	Machine cost	.824	1.879	.724	2.742	3.304	6.886	.724	2.744	.724	2.744
Shocking	Labor		.600		.540		1.600		.540		.604
Raking	Man labor	.252									
	Horse labor	.275									
	Machine cost	.340	.867								
Stacking	Man labor										
	Horse labor		3.876				3.876				
	Machine cost										
Threshing	Cost per bu.			.100	11.640			.100	12.708	.050	10.828
Manuring	Man labor										
	Horse labor										
	Manure										
	Machine cost				12.440						
General Expense			3.600		3.600		3.600		3.600		3.600
Land Rental			1.200		1.200		1.200		1.200		1.200
Total Expense per plot			37.401		46.347		28.910		37.141		30.403
						4136 lb					
						stover					
Yield per acre		4000 lb		29.100		37.000		31.770		54.140	
						S C.					
							16,554				
							stover				
							lbs.				
Yield per plot			16,000		116.400		148.000		127.080		216.560
			lbs.				S C				
Value of product	Per ton	6.000				1.570					
	Per bu.			.760		.600		.960		.330	
Value of crop			48.000		88.464		101.800		121.997		71.465
Total profit or loss per acre			2.649		10.529		18.222		21.214		10.265
Total profit or loss on farm			10.599		42.117		72.890		84.856		41.062

Total net profits—$251.524. Gross income per acre—$21.586. Cost per acre—$9.01. Net profit per acre—$12.576.

TABLE V—NEW SALEM 1910

		No. 1 Mac. Wheat		No. 2 Corn		No. 3 Fife Wheat		No. 4 Oats		No. 5 Oats & Peas	
		4½ bu. Wheat at $ .75		½ bu. Corn 4 bu W. Wheat		5 bu. at $ .95 1 bu. Millet at $1.60		8 bu. Oats 1 bu. Millet		2 bu. Oats 6 bu. Peas 2 bu. Millet	
Seed	....	....	$3.375	....	$5.500	....	$6.350	....	$4.000	....	$14.300
Treating	Chemicals ..	.062	....	....	....	.062	....	.100	....	....	....
	Treating ...	.028	....	....	....	.028	....	.045	....	....	....
	Machine cost	.040	.130	....	....	.040	.130	.040	.185	....	....
Seeding	Man labor...	.154	....	.568	....	.319	....	.319	....	.319	....
	Horse labor.	.376	....	.775	....	.752	....	.752	....	.752	....
	Machine cost	.225	.775	.348	1.691	.300	1.371	.300	1.371	.300	1.371
Plowing	Man labor...	.725	....	....	....	1.680	....	1.680	....	1.680	....
	Horse labor.	1.773	....	....	....	2.364	....	2.364	....	2.364	....
	Machine cost	.261	2.759	....	....	.348	4.392	.348	4.392	.348	4.392
Dragging	Man labor...	.138	....	.472	....	.252	....	.403	....	.403	....
	Horse labor.	.359	....	1.499	....	.599	....	.959	....	.959	....
	Machine cost	.068	.565	.068	2.039	.068	.919	.068	1.430	.068	1.430
Discing	Man labor...	.282	....	.164	....	.469	....	.469	....	.469	....
	Horse labor.	.735	....	.184	....	1.105	....	1.105	....	1.105	....
	Machine cost	.356	1.373	.121	.469	.356	1.930	.356	1.930	.356	1.930
Weeding	Man labor...	.232	....	.232	....	.420	....	.232	....	.232	....
	Horse labor.	.229	....	.229	....	.459	....	.229	....	.229	....
	Machine cost	.068	.529	.068	.529	.068	.947	.068	.529	.068	.529

Cultivating	Man labor			3.033							
	Horse labor			3.152							
	Machine cost			.620	6.805						
Cutting	Man labor	.084		1.120		.485					
	Horse labor	.184		1.182		.735					
	Twine	.100		.400		.200					
	Machine cost	.181	.549	3.304	6.006	.724	2.144				
Shocking	Labor		.135		.400		.540				
Raking	Man labor										
	Horse labor										
	Machine cost										
Stacking	Man labor										
	Horse labor				.969						
	Machine cost										
Threshing	Cost per bu.	.100	.830			.100	1.000				
General Expense			3.200		3.200		3.200		3.200		3.200
Land Rental			1.200		1.200		1.200		1.200		1.200
Total expense per plot			15.400		28.808		24.123		18.236		28.352
Yield per acre				500 lb.	5 bu.						
		8.300		Fodder	S. C.	.250					
Yield per plot				2000 lb.	20 bu.						
			8.300	Fodder	S. C.		10.000				
Value of product	Per ton			8.000							
	Per bu.	.910		.500		.910					
Value of crop			7.553		18.000		9.100				
Total profit or loss per acre			—1.962		—2.702		—3.756		—4.559		—7.088
Total profit or loss on farm			—7.847		-10.808		-15.023		-18.236		-28.352

Total net loss—$80.266. Gross income per acre—$1.732. Cost per acre—$5.745. Net loss per acre—$4.013.

TABLE VI—NEW SALEM 1911

		No. 1 Corn		No. 2 Fife Wheat		No. 3 Oats & Peas		No. 4 Mac. Wheat		No. 5 Oats	
		Corn $1.500 W. Wheat $4.000		Wheat $4.750 Clover $1.600 Tim'ty $1.760		Peas $15.000 Oats $ .700 Rye $4.500		Wheat $4.500 Oats $1.600 Tim'ty $1.760		Oats $4.200 Clover $1.600 Tim'ty $1.760 W.Wht $3.000	
Seed			$5.500		$8.110		$20.200		$7.860		$10.560
Treating Seed	Chemicals			.062				.075		.100	
	Treating			.028				.033		.045	
	Machine cost			.040	.130			.040	.148	.040	.185
Seeding	Man labor	1.099		.705		.753		.647		.647	
	Horse labor	1.326		.501		1.503		.752		1.002	
	Machine cost	.498	2.923	.300	1.506	.300	2.556	.300	1.699	.300	1.949
Plowing	Man labor	.907				1.680		1.680		1.680	
	Horse labor	2.364				2.364		2.364		2.364	
	Machine cost	.348	3.619			.348	4.392	.348	4.392	.348	4.392
Sub-Surface Pack.	Man labor	.205									
	Horse labor	.800									
	Machine cost	.356	1.361								
Dragging	Man labor	.495		.380		.380		.380		.380	
	Horse labor	1.199		.959		.959		.959		.959	
	Machine cost	.068	1.762	.068	1.407	.068	1.407	.068	1.407	.068	1.407
Discing	Man labor	.602		.401							
	Horse labor	1.471		.735							
	Machine cost	.356	2.429	.356	1.492						
Cultivating	Man labor	3.034									
	Horse labor	3.152									
	Machine cost	.620	6.806								

Cutting	Man labor	1.039		.242		.504		.242		.336	
	Horse labor	1.182		.367		.551		.367		.735	
	Twine	1.280		.400				.400		.800	
	Machine cost	3.304	6.805	.362	1.371	.824	1.879	.362	1.371	.724	2.595
Shocking	Labor		1.600		.270		.300		.270		.604
Raking	Man labor					.252					
	Horse labor					.275					
	Machine cost					.340	.867				
Stacking	Machine cost										
	Horse labor		3.876				3.876				
	Man labor										
Threshing	Cost per bu.			.100	2.800			.100	2.500	.050	4.200
Manuring	Man labor										
	Horse labor		12.440								
	Manure										
	Machine cost										
General Expense			3.600		3.600		3.600		3.600		3.600
Land Rental			1.200		1.200		1.200		1.200		1.200
Total expense per plot			53.921		21.886		40.277		24.447		30.692
Yield per acre		Silage 10,000 lbs.		7.000		2300 lb		6.250		21.000	
Yield per plot			Silage 40,000 lbs.		28.000		9200 lb		25.000		84.000
Value of product	Per ton	2.000				.600					
	Per bu.			.900				.850		.360	
Value of crop			40.000		25.200		27.600		21.250		30.240
Total profit or loss per acre			—3.480		.828		—3.169		—.799		—.113
Total profit or loss on farm			-13.921		3.316		-12.677		—3.197		—.452

Total net loss—$26.940. Gross income per acre—$7.214. Cost per acre—$8.561. Net loss per acre—$1.347.

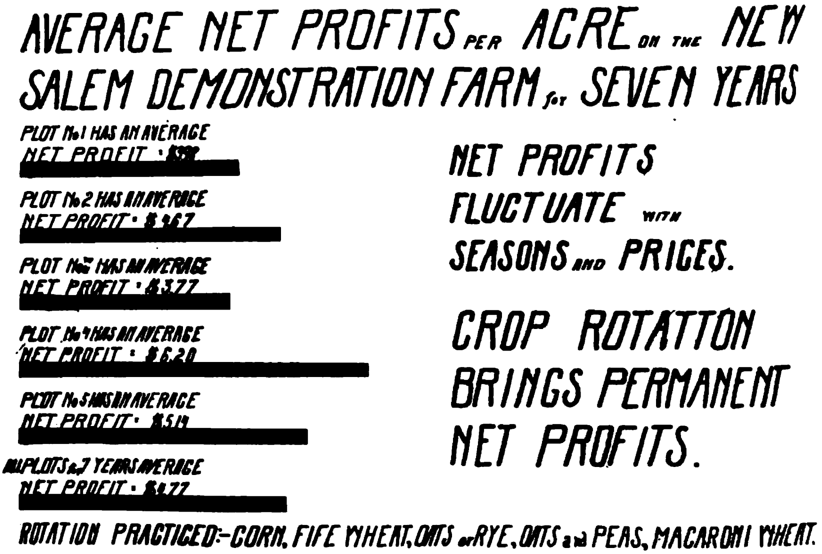
TABLE VII—NEW SALEM 1912

		No. 1 Fife Wheat		No. 2 Oats & Peas		No. 3 Winter Rye		No. 4 Mac. Wheat		No. 5 Corn	
Seed		2½ bu. Wheat at $ .950	$2.375	Peas $15.000 Oats $ .700	$15.700	Tim'ty $ .800 Clover $ .800	$1.600	Wheat $5.100 Tim'ty $ .800 Clover $ .800	$6.700	½ bu. Corn $2.000 3 bu.W. Wheat $2.400	$4.400
Treating Seed	Chemicals	.025						.075			
	Treating	.011						.033			
	Machine cost	.040	.076					.040	.148		
Seeding	Man labor	.102		.192		.500		.205		.568	
	Horse labor	.250		.501				.501		.775	
	Machine cost	.150	.502	.300	.993		.500	.300	1.006	.498	1.841
Plowing	Man labor			.967				.967		.907	
	Horse labor			2.364				2.364		2.364	
	Machine cost			.348	3.679			.348	3.679	.348	3.619
Sub-Surface Pack.	Man labor									.205	
	Horse labor									.800	
	Machine cost									.356	1.361
Dragging	Man labor	.095		.380				.392		.426	
	Horse labor	.239		.959				.959		.959	
	Machine cost	.034	.368	.068	1.407			.068	1.419	.068	1.453
Discing	Man labor	1.692						1.090			
	Horse labor	2.942						1.471			
	Machine cost	.356	4.990					.356	2.917		
Weeding	Man labor					.176					
	Horse labor					.229					
	Machine cost					.068	.473				
Cultivating	Man labor									2.160	
	Horse labor									2.364	
	Machine cost									.620	5.144
						pulled must'd 20 hrs at .169		pulled must'd 20 hrs at .169		Hand Hoed Corn 20 hrs	
Hand hoed	Man labor						3.380		3.880		3.040

Cutting	Horse labor	.735		1.108		.735		.735		1.182	
	Twine	1.200				1.200		1.200		1.280	
	Machine cost	.724	3.144	.824	3.215	.724	3.144	.724	3.144	3.304	6.933
Shocking	Labor		.540		1.200		.540		.540		1.600
Raking	Man labor			.644							
	Horse labor			.550							
	Machine cost			.340	1.534						
Stacking	Man labor										
	Horse labor			7.752	7.752						3.876
	Machine cost										
Threshing	Cost per bu.	.100	17.332			.100	15.084	.100	16.016		
Manuring	Machine cost									12.440	
	Manure										
	Horse labor										12.440
	Man labor										
General Expense			3.600		3.600		3.600		3.600		3.600
Land Rental			1.200		1.200		1.200		1.200		1.200
Total expense per plot			34.127		40.280		29.521		43.749		50.507
										2848 lb	
										stover	
		43.330		5850 lb		37.710		40.040		51.000	
Yield per acre										S. C.	
											11,392
											lbs.
											stover
			173.320		23,400		150.840		160.160		204.000
Yield per plot					lbs						S. C.
Value of product	Per ton			7.000						1.250	
	Per bu.	.710				.400		.720		.400	
										7.120	
										S. C.	
										81.600	
Value of crop			123.057		81.900		60.336		115.315		88.720
Total profit or loss per acre			22.232		10.405		7.704		17.891		9.553
Total profit or loss on farm			88.930		41.620		30.815		71.566		38.213

Total net profits—$271.144. Gross income per acre—$23.466. Cost per acre—$9.909. Net profit per acre—$13.557.

The above tables give the costs that have entered into the production of crops on the thirty-five, four acre fields through a period of seven years which include one of the worst and one of the best years in the history of the Missouri Slope country. Every field on the farm showed a net profit for the period as the chart presented below serves to illustrate.

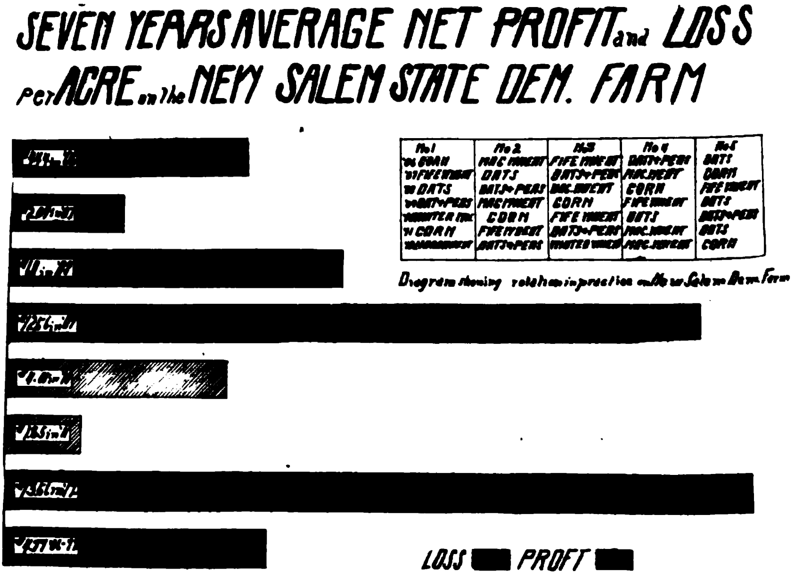


The smallest profit is on plot No. 3, a net return of $3.774 per acre, and the largest on plot No. 4, a net return of $6.205 per acre on practically the same kind of soil. The soil differs very little on the different fields. Some crops are always more profitable than others and when a field happens to have a series of the most profitable crops its net earnings run high, while its neighbor may happen to have a series of low income crops and its net income will be correspondingly low. Below is a table showing the kind of crop average value of produce, cost of production and the average net profit per acre.

Kind of Crop	No. of acres	Total yield	Average yield per acre	Average value of produce per acre	Average cost per acre	Average profit per acre
Hard Wheat	32	539.70 bu.	18.61 bu.	$13.85	$7.55	$6.30
Macaroni Wheat	24	532.56	19.72	15.13	8.26	6.86
Oats	24	614.56	25.60	9.02	6.07	2.95
Oats & Peas	28	91600 lbs	3271 lbs	10.23	8.50	1.73
Corn	28	5668 lbs fodder 566.80 bu. shelled corn	4772 lbs 20.24 bu. shelled corn	14.68	9.27	5.41
*Winter Rye	4	150.84 bu.	37.50	15.08	7.38	7.70

*Grown in 1912 only

Winter rye shows the largest net profit per acre, but that crop was grown only once, and that was in 1912—an exceptionally good year—and it showed the lowest net profit of any crop during the year in which it was grown. Macaroni wheat shows the highest net profit, a sum equal to $6.864 per acre despite the fact that the price obtained was sometimes as much as twenty cents less per bushel than hard wheat sold for. Macaroni wheat did not have as favorable place in the rotation as the hard wheats since they followed the corn crop, and macaroni wheat followed oats and peas cut for hay; a crop that is hard on soil moisture.There are two fields of hard wheat in 1910 and no macaroni wheat that year, consequently the hard wheat lost heavily in net profits and the macaroni wheat was exempt from the depressing effects of that rather disasterious season. The lower cost of production $ .755 per acre of the hard wheats as compared with the macaroni wheat, is corn land which did not require plowing. Oats and peas yielded the lowest net profit ($1.729 per acre) of any variety of crop grown on this farm. This is partly due to the high cost of pea seed and to the fact that the crop was often cut before it should have been harvested to prevent the ripening of yellow mustard, a noxious weed this farm was infested with when it was first taken for demonstration farm purposes. Oats is a crop of low income, low cost of production and low net profits. Corn shows a very satisfactoy net profit of $5.412 per acre without any consideration of the better condition in which it leaves the land for the the hard wheat crop. Corn is the crop showing the highest cost of produc- $5.412 per acre without any consideration of the better condition in which it leaves the land for the hard wheat, and a good deal of the net profit credited to hard wheat may be indirectly due to the cultivation given the corn crop. Corn is the crop showing the highest cost of production per acre but the net profit to the acre is also large. With the increased yields of corn that may be obtained thru the acclimatization and breeding up of the corn plant together with a little more intensive cultivation, corn may easily become the most profitable crop in such a five year rotation as that used at New Salem. The Net Profit per acre is $4.774 on the average for seven years at New Salem, although two of these years were far below the normal in rainfall and favorable condition for plant growth. Below is a graphic illustration showing the profits and losses for the seven years 1906-1912 inclusive.



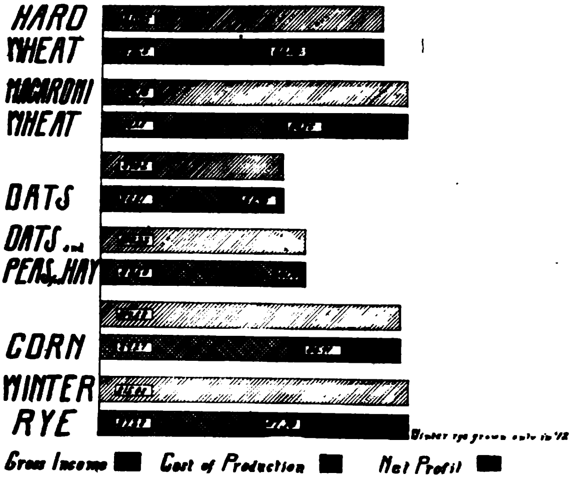
No 1	No 2	No 3	No 4	No 5
'06 CORN	MAC WHEAT	FIFE WHEAT	OATS+PEAS	OATS
'07 FIFE WHEAT	OATS	OATS+PEAS	MAC WHEAT	CORN
'08 OATS	OATS+PEAS	MAC WHEAT	CORN	FIFE WHEAT
'09 OATS+PEAS	MAC WHEAT	CORN	FIFE WHEAT	OATS
'10 WINTER [illegible]	CORN	FIFE WHEAT	OATS	OATS+PEAS
'11 CORN	FIFE WHEAT	OATS+PEAS	MAC WHEAT	OATS
[illegible]	OATS+PEAS	WINTER WHEAT	MAC WHEAT	CORN

Diagram showing rotation in practice on the New Salem Dem. Farm

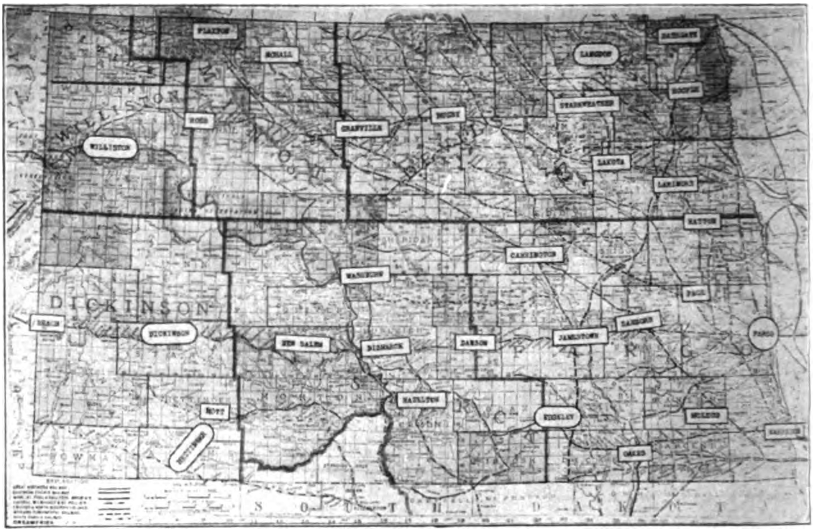
Two of these years 1910 and 1911 respectively show a net loss per acre but the other five show a net profit each year. If the three years 1909, '10, and '11 be grouped together there is an average net profit of $2.399 per acre; while the three years 1910, '11, and '12 be grouped together, the annual net profit would average $2.733 per acre. If the prices of 1911 had prevailed in 1912, the extra income would have been; for hard wheat $ .18 per bushel, oats and peas $2.20 per ton, rye $ .30 per bushel, macaroni wheat $ .12 per bushel and corn $ .15 per bushel, and the net income of the demonstration farm would have been $420.812 or a net profit of $21.040 per acre instead of $13.557, as it actually was with 1912 prices. This shows that net profits in any one year depend as much on selling price as upon the rotation and cultural methods, and that only over a period of seven years such as this farm has run can a definite rotation and methods demonstrate what it is worth in net profits per acre. The graphic illustration below illustrates the fact that all crops were grown at a net profit, as well as showing a gross income, cost of production, and net profits per acre of each crop.

RESULTS of SEVEN YEARS of CROP ROTATION.... NEW SALEM
STATE DEMONSTRATION FARM.

GROSS INCOME minus COST OF PRODUCTION equal NET PROFIT PER ACRE



The fact that a net profit of $4.774 per acre was obtained for seven years, clearly demonstrates that a five year rotation like that used at New Salem is both profitable and practicable for farmers on the Missouri Slope to adopt on their farms.



The map above shows the location of the Government Experiment Station at Fargo, in the form of a Circle, the sub-stations in the form of ovals, and the demonstration farms as rectangular figures. At these points, the North Dakota Experiment Station is gathering data in regard to the agricultural conditions in the State which will be of great value to the farmers and business men of North Dakota in years to come.

Net Profits at Bathgate. The first farm to be put in operation on typical Red River valley soil, is located four miles Northeast of Bathgate. This farm has now been in operation a period of six years. It has a six year rotation, therefore, there has been thirty-six fields of crop consisting of four acres each produced in that time. There is but one other farm located in the Red River Valley as early as 1907, and that is the farm at Larimore. That farm is not typical of the heavy clay soil which is characteristic of the Red River Valley proper. According to the chemical analysis (See table Page 76) this soil is very rich in all essential plant foods. Mr. E. G. Schollander who located this farm has the following to say in the First Annual report of Demonstration farms; "This land lies in the heart of the Red River Valley. It has been farmed almost continually since that part of the country was broken up. The land is badly infected with weeds commonly known as Kinghead, Canada thistle, sow thistle, and wild oats. The weed question alone, makes the land ideal to show whether thorough cultivation can clean it from the above pests." The six year rotation and cultivation given have not entirely eliminated the above mentioned noxious weeds, but it has very greatly reduced their numbers. The land on this farm was broken up in 1882, and has been in continuous cultivation since. It is sometimes overflowed with water, and the drainage is poor particularly on the south end of the fields. The soil is a heavy black "gumbo" characteristic of the heavier soils of the Red River Valley.

Below are six tables showing the crops grown, the expense items and cost of each in the production of the crops, together with the total expense of production, market price total income, and total net profit or loss for each field on the Bathgate farm for 1907 to 1912 inclusive.

TABLE VIII—BATHGATE 1907

		No. 1 Barley & Clover		No. 2 Barley & Clover		No. 3 Corn		No. 4 Oats		No. 5 Wheat		No. 6 Wheat	
		Barley $1.75 Clover $1.95		Barley $1.75 Clover $1.95		Corn $1.50		Oats $2.40		Wheat $3.75		Wheat $3.75	
Seed		$3.700		$3.70			$1.500		$2.400		$3.750		$3.75
'reating Seed	Chemicals	.062		.062				.100		.062		.062	
	Treating	.028		.028				.045		.028		.028	
	Machine cost	.040	.130	.040	.130			.040	.185	.040	.130	.040	.130
Seeding	Man labor	.192		.192		.403		.192		.192		.192	
	Horse labor	.501		.501		.525		.501		.501		.501	
	Machine cost	.300	.993	.301	.993	.348	1.276	.300	.993	.300	.993	.300	.993
Plowing	Man labor	1.750						1.750		1.750		1.750	
	Horse labor	2.955						2.955		2.364		2.364	
	Machine cost	.348	5.053					.348	5.053	.348	4.462	.348	4.462
Dragging	Man labor	.276		.276		.368		.368		.368		.368	
	Horse labor	.719		.899		.959		.959		.959		.959	
	Machine cost	.068	1.063	.068	1.243	.068	1.395	.068	1.395	.068	1.395	.068	1.395
Cultivating	Man labor					4.550							
	Horse labor					4.728							
	Machine cost					.620	9.898						
Cutting	Man labor	.485		.485		1.120		.522		.485		.485	
	Horse labor	.735		.735		1.182		.735		.735		.735	
	Twine	.640		.640		1.280		.800		.560		.560	
	Machine cost	.724	2.584	.724	2.584	3.304	6.886	.724	2.781	.724	2.504	.724	2.504

Shocking	Labor		.624		.624		1.600		.604		.540		.540
Stacking	Man labor												
	Horse labor						3.876						
	Machine cost												
Threshing	Cost per bu.	.060	5.328	.060	5.328			.050	6.000	.100	5.600	.100	5.600
Manuring	Man labor												
	Horse labor												
	Manure				6.220								
	Machine cost												
General Expense			3.600		3.600		3.600		3.600		3.600		3.600
Land Rental			9.600		9.600				9.600		9.600		9.600
Total Expense per acre			32.675		34.022		39.631		32.611		32.574		32.574
Yield per acre		22.200		22.200		4920 lb		30.000		14.000		14.000	
Yield per plot			88.800		88.800		196.800		120.000		56.000		56.000
Value of product	Per ton					6.000	lbs						
	Per bu.	.800		.800				.450		.900		.900	
Value of crop			71.040		71.040		59.040		54.000		50.400		50.400
Total profit or loss on farm			38.365		37.018		19.409		21.389		17.826		17.826
Total profit or loss per acre			9.591		9.254		4.852		5.347		4.456		4.456

Total net profits—$151.833. Gross income per acre—$14.830. Cost per acre—$8.503. Net profit per acre—$6.326.

TABLE IX—BATHGATE 1908

		No. 1 Wheat		No. 2 Clover		No. 3 Wheat		No. 4 Corn		No. 5 Corn		No. 6 Barley & Clover	
		Wheat $5.00				Wheat $5.00		Corn $1.50		Oats $4.00		Barley $4.50 Clover $9.00	
Seed			$5.00				$5.00		$1.50		$4.00		$13.500
Treating Seed	Chemicals	.062				.062				.100		.075	
	Treating	.028				.028				.045		.337	
	Machine cost	.040	.130			.040	.130			.040	.185	.040	.452
Seeding	Man labor	.192				.192		.806		.192		.192	
	Horse labor	.501				.501		1.050		.501		.501	
	Machine cost	.040	.993			.300	.993	.348	2.204	.300	.993	.300	.993
Plowing	Man labor	1.680		1.750		1.750		.908					
	Horse labor	2.955		2.955		2.955		2.364					
	Machine cost	.348	4.983	.348	5.053	.348	5.053	.348	3.620				
Dragging	Man labor	.196				.092		.184		.184		.184	
	Horse labor	.479				.239		.479		.479		.479	
	Machine cost	.068	.743			.068	.399	.068	.731	.068	.731	.068	.731
Rolling	Man labor	.205				.205							
	Horse labor	.800				800							
	Machine cost	.356	1.361			.356	1.361						
Discing	Man labor					.564		Hand					
	Horse labor					1.471		hoed					
	Machine cost					.356	2.391	10 hrs.	1.528				
Cultivating	Man labor							3.677					
	Horse labor							3.940					
	Machine cost							.620	8.237				
Cutting	Man labor	.485		1.288		.485		1.120		.485		.485	
	Horse labor	.735		1.103		.735		1.182		.735		.735	
	Twine	.640				.960		1.280		.400		.640	
	Machine cost	.724	2.584	.824	3.215	.724	2.904	3.304	6.886	.724	2.344	.724	2.584

Shocking	Labor		.540		1.200		.540		1.600		.604		.624
Raking	Man labor			.644									
	Horse labor			.550									
	Machine cost			.340	1.534								
Stacking	Man labor												
	Horse labor												
	Machine cost				3.876				3.876				
Threshing	Cost per bu.	.100	6.164		8.000	.100	10.200			.050	4.100	.060	4.920
Manuring	Man labor												
	Horse labor		12.440										
	Manure												
	Machine cost												
General Expense			3.600		3.600		3.600		3.600		3.600		3.600
Land Rental			10.800		10.800		10.800		10.800		10.800		10.800
Total Expense per plot			49.338		37.278		43.371		44.582		27.357		38.204
Yield per acre				1000 lb									
		15.410		2.750		25.500		4312 lb		21.000		20.500	
				Seed									
Yield per plot					4000 lb.								
					hay								
			61.640		11.000		102.000		17,248		84.000		82.000
					Seed				lbs.				
Value of product	Per ton			12.000				8.000					
	Per bu.	.950				.950				.350		.500	
Value of crop			58.567		152.000		96.900		68.992		29.400		41.000
Total profit or loss per plot			9.229		114.722		53.529		24.410		2.043		2.796
Total profit or loss per acre			2.307		28.680		13.382		6.102		.511		.699

Total net profit—$206.729. Gross income per acre—$18.619. Cost per acre—$10.005. Net profit per acre—$8.613.

TABLE X—BATHGATE 1909

		No. 1 Oats		No. 2 Wheat		No. 3 Barley & Clover		No. 4 Wheat		No. 5 Oats & Peas		No. 6 Barley	
		Oats $3.20		Wheat $6.25 Clover $1.60		Barley $2.40 Clover $12.00		Wheat $6.25 Clover $1.60		Oats $8.00 Peas $10.50 W. Rye $6.00		Barley $2.40 Millet $3.00	
Seed			$3.200		$7.850		$14.400		$7.850		$17.300		$5.40
Treating Seed	Chemicals	.100		.062		.075		.062				.750	
	Treating	.045		,028		.337		.028				.337	
	Machine cost	.040	.185	.040	.130	.040	.452	.040	.130			.040	1.127
Seeding	Man labor	.192		.192		.192		.192		.548		.482	
	Horse labor	.501		.501		.501		.501		1.003		1.002	
	Machine cost	.300	.993	.300	.993	.300	.993	.300	.993	.300	1.851	.300	1.784
Plowing	Man labor	1.680						1.680		2.467		2.945	
	Horse labor	2.955						2.955		5.319		5.319	
	Machine cost	.348	4.983					.348	4.983	.348	8.134	.348	8.612
Dragging	Man labor	.184		.184		.184		.092		.354		.242	
	Horse labor	.479		.479		.479		.239		.719		.479	
	Machine cost	.068	.731	.068	.731	.068	.731	.068	.399	.068	1.141	.068	.789
Discing	Man labor							.564					
	Horse labor							1.471					
	Machine cost							.356	2.391				
Rolling	Man labor			.205								.270	
	Horse labor			.800								.800	
	Machine cost			.356	1.361							.356	1.426
Cutting	Man labor	.485		.485		.485		.485		.727		.522	
	Horse labor	.735		.735		.735		.735		.551		.735	
	Twine	1.000		.800		.600		.800				.800	
	Machine cost	.724	2.944	.724	2.744	.724	2.544	.724	2.744	.824	2.102	.724	2.781

Shocking	Labor		.604		.540		.624		.540		.600		.624
Raking	Man labor									.364			
	Horse labor									.275			
	Machine cost									.340	.979		
Stacking	Man labor												
	Horse labor										3.876		
	Machine cost												
Threshing	Cost per bu.	.050	9.674	.100	8.660	.060	3.187	.100	7.788			.060	5.429
Manuring	Horse labor												
	Machine cost		12.440										
	Manure												
General Expense			3.600		3.600		3.600		3.600		3.600		3.600
Land Rental			10.800		10.800		10.800		10.800		10.800		10.800
Total Expense per plot			50.154		37.409		37.331		42.218		50.383		42.372
Yield per acre		48.870		21.650		13.280		19.470		2075 lb		22.620	
Yield per plot			193.480		86.660		53.120		77.880		8300 lb		90.480
Value of product	Per ton									8.000			
	Per bushel	.350		1.000		.450		1.000				.450	
Value of crop			67.710		86.660		23.940		77.880		33.200		40.720
Total profit or loss per acre			17.556		49.251		13.391		35.662		17.183		1.652
Total profit or loss on farm			4.389		12.813		3.348		8.915		4.298		.413

Total net profit—$70.248. Gross income—$13.753. Cost per acre—$10.827. Net profit per acre—$2.926.

TABLE XI—BATHGATE 1910

		No. 1 Corn		No. 2 Clover		No. 3 Clover		No. 4 Barley & Clover		No. 5 Barley		No. 6 Wheat	
		Corn $1.50						Barley $2.400 Clover $8.00		Barley $3.20 Clover $1.60		Wheat $4.00	
Seed			$1.500						$10.400		$4.800		$4.000
Treating Seed	Chemicals							.075		.100		.062	
	Treating							.033		.045		.028	
	Machine cost							.040	.148	.040	.185	.040	.130
Seeding	Man labor	.043						.192		.253		.205	
	Horse labor	.525						.501		.501		.501	
	Machine cost	.348	1.276					.300	.993	.300	1.054	.300	1.006
Plowing	Man labor			1.750		1.750		1.680		2.875		1.334	
	Horse labor			2.955		2.955		2.955		5.319		2.364	
	Machine cost			.348	5.053	.348	5.053	.348	4.983	.348	8.542	.348	4.046
Dragging	Man labor	.380						.380		.363		.098	
	Horse labor	.959						.959		.719		.239	
	Machine cost	.068	1.407					.068	1.407	.068	1.150	.068	.405
Discing	Man labor	1.109		.545		.545							
	Horse labor	2.206		.735		.735							
	Machine cost	.356	3.671	.356	1.636	.356	1.636						
Weeding	Man labor	.232								.210			
	Horse labor	.229								.229			
	Machine cost	.068	.529							.068	.507		
Cultivating	Man labor	5.155											
	Horse labor	5.516											
	Machine cost	.620	11.291										
Cutting	Man labor	1.120		1.841		1.341		.836		.485		.485	
	Horse labor	1.182		1.108		1.102		.735		.735		.735	
	Twine	1.280						.320		.240		.480	
	Machine cost	3.304	6.886	.824	3.268	.824	3.267	.724	2.115	.724	2.184	.724	2.424

Shocking	Labor		1.600		1.200		1.200		.624		.624		.540
Raking	Man labor			.671		.671							
	Horse labor			.551		.551							
	Machine cost			.340	1.562	.340	1.562						
Threshing	Cost per bu.				3.876		3.876	.060	1.632	.060	3.660	.100	5.200
Manuring					12.440								
Hauling	Man labor Horse labor Machine cost		3.876										
General Expense			3.600		3.600		3.600		3.600		3.600		3.600
Land Rental			12.000		12.000		12.000		12.000		12.000		12.000
Total Expense per plot			47.636		44.635		32.194		37.902		38.306		33.351
Yield per acre		2520 lb stover 35 bu. S. Corn		1790 lb hay 1.900 seed		2116 lb hay 1.68 seed		6.800		15.250		13.000	
Yield per plot			10,000 lbs stover 140.000 S. Corn		1790 lb. hay 7.600 seed		8464 lb hay 6.72 seed		27.200		61.000		52.000
Value of product	Per ton		2.000		9.000		9.000						
	Per bu.		.550		12.333		12.333	.600		.600		.950	
Value of crop			87.640		125.950		120.966		16.320		35.600		49.400
Total profit or loss per plot			40.004		81.315		88.772		-21.582		—1.706		16.049
Total profit or loss per acre			10.001		20.326		22.193		—5.395		—.426		—4.012

Total net profit—$202.852. Gross income per acre—$18.203. Cost per acre—$9.751. Net profit per acre—$8.452.

TABLE XII—BATHGATE 1911

		No. 1 Wheat		No. 2 Corn		No. 3 Wheat		No. 4 Oats & Peas		No. 5 Barley & Clover		No. 6 Oats	
Seed		Wheat $5.00 Clover $1.46	$6.460	Corn $1.50	$1.500	Wheat $5.00 Clover $2.00	$7.000	Oats & Peas $12.80	$12.800	Barley $2.40 Clover $8.00	$10.400	Oats $3.20 Clover $2.00	$5.200
Treating Seed	Chemicals	.062				.062				.075		.100	
	Treating	.028				.028				.033		.045	
	Machine cost	.040	.130			.040	.130			.040	.148	.040	185
Seeding	Man labor	.205		.403		.205		.410		.193		.192	
	Horse labor	.501		.525		.501		1.002		.501		.501	
	Machine cost	.300	1.006	.348	1.276	.300	1.006	.300	1.712	.300	.994	.300	.994
Plowing	Man labor	1.680				1.680		1.559				1.750	
	Horse labor	2.955				2.955		2.955				2.955	
	Machine cost	.348	4.983			.348	4.983	.348	4.862			.348	5.053
Dragging	Man labor	.288		.524		.288		.392		.288		.190	
	Horse labor	.719		1.199		.719		.959		.719		.479	
	Machine cost	.068	1.075	.068	1.791	.068	1.075	.068	1.419	.068	1.075	.068	.727
Discing	Man labor	.602		.564				.282		.282		.282	
	Horse labor	1.471		1.471				.735		.735		.735	
	Machine cost	.356	2.429	.356	3.191			.356	1.373	.356	1.373	.356	1.373
Weeding	Man labor			.696								.232	
	Horse labor			.687								.229	
	Machine cost			.068	1.451							.068	.529
Hand hoed	Labor			Hand hoed 10 hrs.	1.528								
Cultivating	Man labor			5.270									
	Horse labor			5.516									
	Machine cost			.620	11.406								
Cutting	Man labor	.485		1.120		.485		.504		.485		.485	
	Horse labor	.735		1.182		.735		.552		.735		.735	
	Twine	.800				.800				.960		.960	
	Machine cost	.724	2.744	3.804	5.606	.724	2.744	.824	1.880	.724	2.904	.724	2.904

Shocking	Labor		.540		1.600		.540		.600		.624		.604
Raking	Man labor							.252					
	Horse labor							.276					
	Machine cost							.340	.868				
Threshing	Cost per bu.	.100	11.200			.100	9.500			.060	9.360	.050	11.600
Manuring	Machine cost Horse labor Man labor											12.440	12.440
General Expense			3.600		3.600		3.600		3.600		3.600		3.600
Land Rental			12.000		12.000		12.000		12.000		12.000		12.000
Total Expense per plot			46.167		44.949		42.578		41.114		42.478		57.209
				3508 lb									
				stover									
				36.000		23.750		4392½		39.000		58.000	
Yield per acre		28.000		S.Corn				lbs					
					14,032								
					stover								
			112.000		144.000		95.000		17,570		156.000		232.000
Yield per plot					S. Corn				lbs				
	Per ton			2.000				12.000					
Value of product	Per bu.	.950		.600		.950				.980		.400	
Value of crop			106.400		100.430		90.250		105.420		152.880		92.800
Total profit or loss on farm			60.233		55.481		47.672		64.306		110.402		35.591
Total profit or loss per acre			15.058		13.870		11.918		16.076		27.600		8.898

Total net profits—$373.685. Gross income per acre—$27.007. Cost per acre—$11.435. Net profit per acre—$15.572.

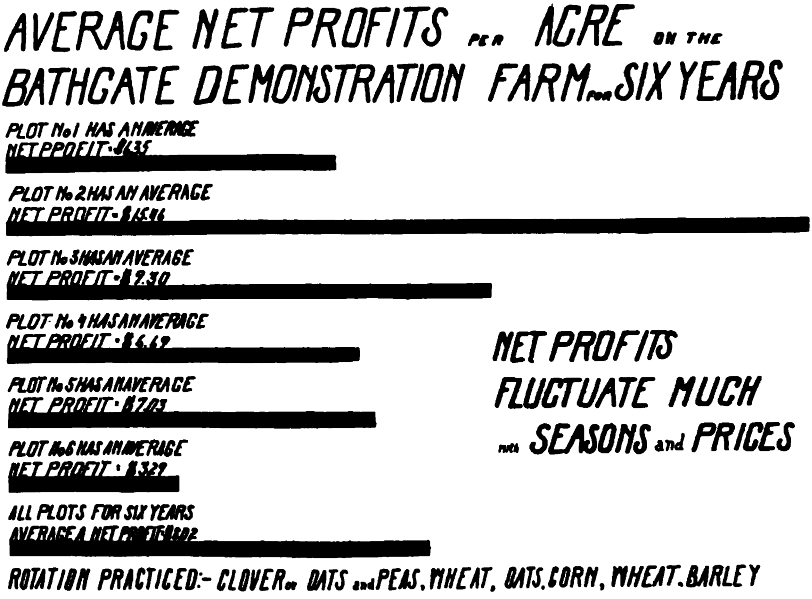
TABLE XIII—BATHGATE 1912

		No. 1 Barley		No. 2 Wheat		No. 3 Oats		No. 3 Wheat		No. 5 Oats Peas		No. 6 Corn	
		Barley $12.000		Wheat $5.000 cl. .750		Oats $3.200		Wheat $5.000		Peas $15.000 Oats $ .800		Corn $2.500	
Seed			$12.000		$5.750		$3.200		$5.000		$15.800		$2.500
Treating Seed	Chemicals	.150		.062		.100		.062					
	Treating	.066		.028		.045		.028					
	Machine cost	.040	.256	.040	.130	.040	.185	.040	.130				
Seeding	Man labor	.445		.205		.192		.205		.410		.403	
	Horse labor	1.003		.501		.501		.501		1.003		.525	
	Machine cost	.300	1.748	.300	1.006	.300	.994	.300	1.006	.300	1.713	.348	1.276
Plowing	Man labor	2.945		1.680		1.559		1.680		2.526			
	Horse labor	5.910		2.955		2.955		2.955		5.900			
	Machine cost	.348	9.203	.348	4.983	.348	4.862	.348	4.983	.348	8.784		
Dragging	Man labor	.645		.196		.380		.392		.196		.282	
	Horse labor	.479		.479		.959		.959		.479		.719	
	Machine cost	.068	1.192	.068	.743	.068	1.407	.068	1.419	.068	.743	.068	1.069
Discing	Man labor	.564		.602		1.534				.301		.564	
	Horse labor	1.470		1.470		2.942				.735		1.471	
	Machine cost	.356	2.390	.356	2.428	.356	4.832			.356	1.392	.356	2.391
		Rolled											
Weeding	Man labor	.270		.408				.232				.464	
	Horse labor	.800		.459				.229				.459	
	Machine cost	.356	1.426	.068	.935			.068	.529			.068	.991
Cultivating	Man labor											4.550	
	Horse labor											4.728	
	Machine cost											.620	9.909
Hail loss					1.600		.800		1.600		.800		.800

Cutting	Man labor	.522		.485		.504		.485		.727		1.120	
	Horse labor	.735		.735		.551		.735		.551		1.182	
	Twine	1.000		1.000				1.000					
	Machine cost	.724	2.981	.724	2.944	.824	1.879	.724	2.944	.824	1.711	3.304	5.606
Shocking	Labor		.624		.540		.600		.540		.600		1.600
Raking	Man labor					.252				.363			
	Horse labor					.275				.275			
	Machine cost					.340				.340			
							.867				.978		
Stacking	Man labor												
	Horse labor					3.876	3.876			3.876	3.876	3.876	3.876
	Machine cost												
Threshing	Cost per bu.		7.200	.100	11.200			.100	10.800				
Manuring	Man labor												
	Horse labor						12.440						
	Manure												
	Machine cost												
General Expense			3.600		3.600		3.600		3.600		3.600		3.600
Land Rental			12.000		12.000		12.000		12.000		12.000		12.000
Total Expense per plot			54.620		47.859		51.542		44.551		51.997		45.618
Yield per acre		30.000		28.250		4181 lb		27.000		6087 lb		4500 lb	
Yield per plot			120.000		113.000		16,724		108.000		24,348		18,000
Value of product	Per ton					9.000	lbs.			9.000	lbs.	6.000	lbs.
	Per bu.	.350		.750				.750					
Value of crop			42.000		84.750		75.260		81.000		109.564		54.000
Total profit or loss per farm			12.620		36.891		23.718		36.449		57.567		8.382
Total profit or loss per acre			3.155		9.223		5.929		9.112		14.392		2.090

Total net profits—$150.387. Gross income per acre—$18.607. Cost per acre—$12.390. Net profit per acre—$6.267.

The above tables give the costs that have entered into the production of crops on the thirty-six fields through a period of six years, one entire rotation cycle, and they are probably close to average years of crop production in the Red River Valley. Every field on the farm showed a net profit (though they varied widely) for the period as the graphic illustration below demonstrates.

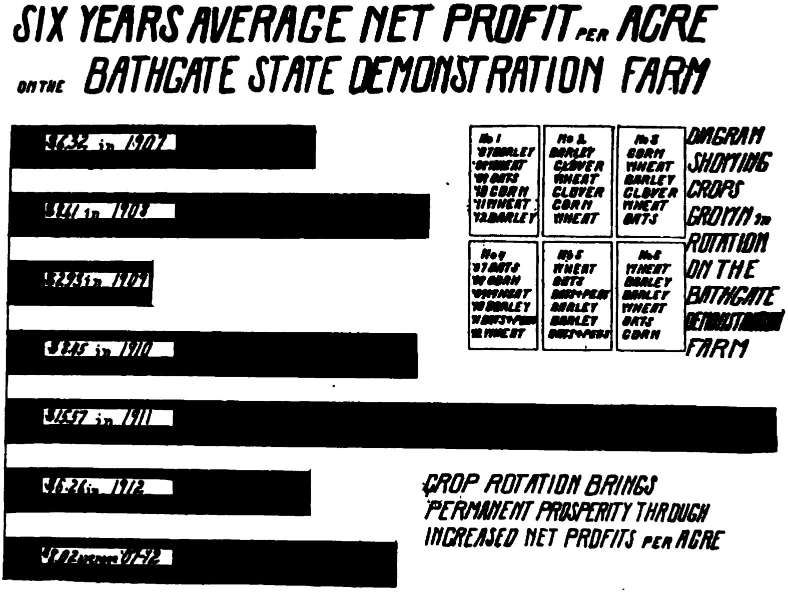


The same rotation was practiced on all fields, but it was twice voluntarily changed. In 1910 a good crop of volunteer clover was allowed to grow instead of seeding oats, as the rotation called for. In 1909 oats and peas were sown on plot No. 5 instead of corn as the rotation was planned for, and winter rye was seeded that fall. It failed to make a good stand so barley was seeded instead, this crop taking the place of wheat on one field in 1910. When the clover failed either oats and peas were sown for hay, or barley for grain was substituted. The great difference in net profits on the different plots such as No. 2 and No. 6 where the soil is almost identically the same is due to the fact that No. 2 happened to produce heavy crops in seasons of high prices and No. 6 was particularly unfortunate in having rather low yields, and the crops usually found low prices in the cycle of rotation.

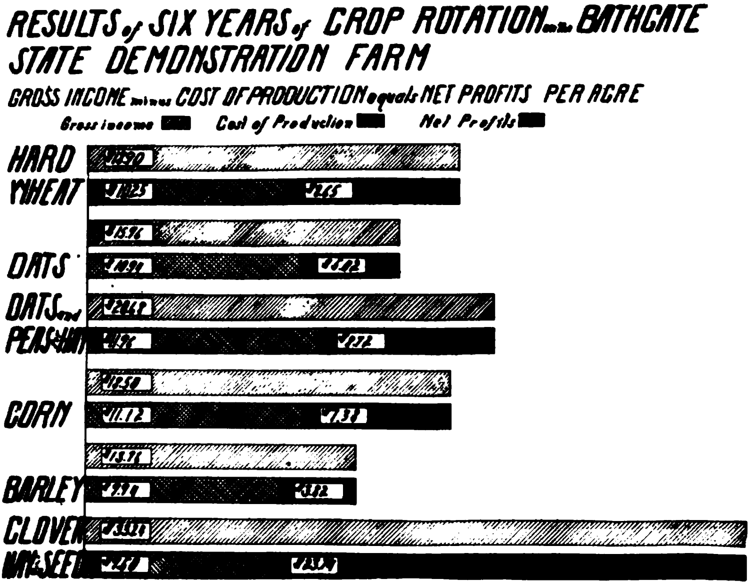
Below is a table showing the kind of crop, acreage, total yield, average yield per acre, average value of produce per acre, cost of production per acre and the average net profit per acre.

Kind of Crop	No. of Acres	Total yield	Average yield per acre	Average value of produce per acre	Average cost of production per acre	Average net profit per acre
Hard wheat	44	920.18	20.91	$18.905	$10.257	$8.648
Oats	20	629.48 bu. 16724 lbs hay	39.34 4181 lbs hay	15.958	10.943	5.015
Oats & Peas	12	50218 lbs hay	4184 lbs hay	20.682	11.958	8.724
Corn	20	100052 lbs fodder 284 bu.	5026 lbs fodder 14.20 lbs	18.505	11.121	7.384
Barley	36	767.40	21.32	13.765	9.942	3.823
Clover	12	25.32 bu. seed 19624 lbs hay	2.11 bu. seed 1635 lbs hay	33.242	9.509	23.733

Barley shows the lowest net profit $3.82 per acre. The barley crop was always charged with the cost of the clover seed. Had this item, when the clover crop was a success, been charged to the clover crop the folowing year; and when the clover failed to catch had been charged to the general expense, the net profit of the barley crop would have been over a dollar more per acre, and other crops particularly the clover crop would have shown a less net profit. Oats have a net profit equal to $5.01 per acre. Corn has a net income of $7.38 per acre, which is nearly two dollars more per acre than at New Salem. Oats and peas were only grown on three different years, and the net profit is quite high $8.72 per acre. This to some extent is due to the high prices prevailing for hay these years. Wheat shows the very satisfactory yield of 20.91 bushells per acre on the average, the total income per acre being equal to $18.905, and the average cost of production being $10.25 per acre leaving a net profit equal to $8.64 per acre. Clover shows the largest net profit of any crop produced on this farm; the three fields give an average gross income equal to $33.240 per acre, the average cost per acre was $9.510 and the net income was equal to $23.73 per acre. This shows clover to be a highly profitable crop to grow in the parts of the Red River Valley adapted to its culture. **The Net profit per acre is $8.027 on the average for six years at Bathgate.** Net profits vary greatly in different years as the following graphic illustration shows clearly.

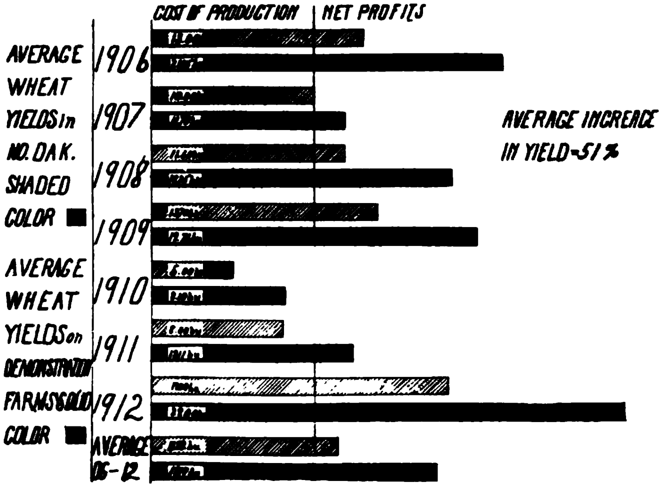


The poorest crop was in 1909 and the best in 1911. The actual yields in 1912 were nearly as good as in 1911, but the prices were so much lower that the net profits were over $9.30 less per acre than they were in 1911. Every year at Bathgate showed a net profit per acre, but several plots in that time were operated at a loss, particularly those producing barley. As at New Salem all varieties of of crops grown showed a net profit per acre. The graphic illustration below ilustrates this fact at the same time showing the gross income, the cost of production and the net profit for each crop per acre.



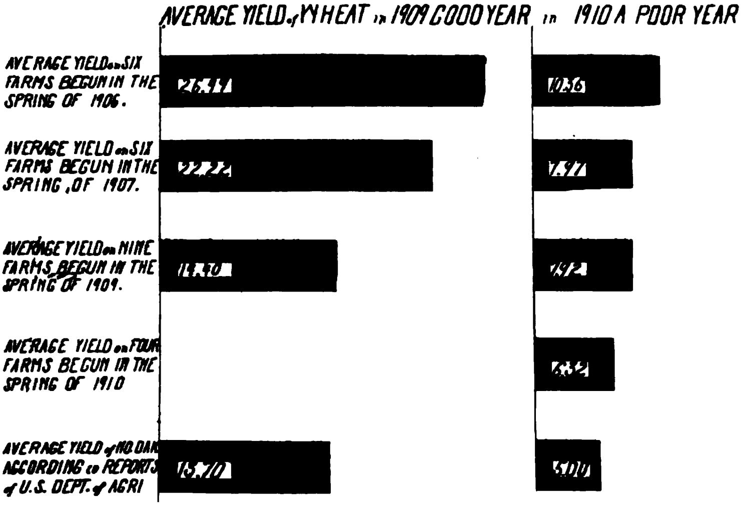
The yields of wheat averaged, in North Dakota according to the reports of the United States Department of Agriculture for the years 1905 to 1912 inclusive, but 11.32 bushels per acre. The illustration below shows the average yields obtained in the state according to the United States Agricultural Department report, and the yield (an average of 17.19 bushels per acre) obtained on the State Demonstration Farms for the corresponding years.

A COMPARISON of the AVERAGE WHEAT YIELDS for SEVEN YEARS



In every case the yields of wheat have averaged considerably above the average of the state, and the longer the farms are worked, the more this is apparent. The first year the farms are just under a systematic rotation, they have had no beneficial effects from previous years rotations. This is very clearly shown in both the exceptionally good year 1909 and the exceptionally poor season which followed it, by illustration which appears below.

RESULTS of CROP ROTATION on DEM. FARMS



This illustration shows that a good rotation does not increase the wheat yield markedly the first year, but the second year shows an increase, while the third and fourth years show a marked increase both in good and bad years, and the longer wheat is grown continually the smaller the yields become. When grown in rotation the average yield per acre tends to rapidly go up to twenty bushels per acre, and it will probably stay around that figure on a ten year average. In Minnesota (See page 45 bulletin No. 117) "wheat is not profitable when yields of less than twelve bushels are obtained." In North Dakota wheat is probably profitable when over ten bushels is produced per acre as our land values are considerably lower, and in consequence the land rental is lower. If it takes ten bushels to pay the cost of producing an acre of wheat on the average in North Dakota, and if the average yield is 11.32 bushels per acre, the profit has been approximately a bushel and a third per acre per year; And on the same basis the net profits on the state Demonstration farms would be approximately seven bushels per acre. In other words, a farm systematically rotated will make a larger net income from wheat when but two-fifths of the farm is in this crop than would be made from the entire farm in this crop continuously for a period of seven years.

CONCLUSION.

The New Salem Demonstration Farm has been in operation for seven years. It is a farm typical of the Missouri Slope region. It has a five year rotation consisting of the following crops in the order named:

Corn
Fife wheat
Oats or winter rye
Oats and peas
Macaroni wheat.

An acre of hard wheat at New Salem cost $7.54 to produce, and yielded a net profit of $6.31 an acre. Macaroni wheat cost $8.26 to produce, and yielded a net profit of $6.86 an acre. Oats cost $6.06 to produce, and yielded a net profit of $2.95 an acre. Oats and Peas cost $8.50 to produce, and yielded a net profit of $1.73 an acre. Corn cost $9.27 to produce and yielded a net profit of $5.41 an acre. Winter rye (one year 1912) cost $7.58 to produce and yieded a net profit of $7.70 an acre.

The Bathgate demonstration farm has been in operation for six years. It is located on typical Red River valley soil and is quite characteristic of a large section of the Red River Valley. The rotation used on this farm is a six year rotation consisting of the following crops in the order named:

Clover or oats and peas
Wheat
Oats
Corn
Wheat and
Barley in which clover is seeded for the crop of following year.

Wheat at Bathgate costs $10.25 to produce and yielded a net profit of $8.64 an acre. Oats cost $10.94 to produce and yielded a net profit of $5.01 an acre. Oats and peas cost $11.95 to produce and yielded a net profit of $8.72 an acre. Corn cost $11.12 to produce and yielded a net profit of $7.38 an acre. Barley cost $9.94 to produce and yielded a net profit of $3.82 an acre. Clover cost $9.50 to produce and yielded a net profit of $23.75 an acre.

No commercial fertilizers were used on these farms. Barnyard manure was applied once to each field at the rate of ten loads per acre during a rotation cycle or once every five or six years.

Average farm land is selected for the demonstration farms, good tillage is given, pedigree seed is used, and no more work or expense is put on the land than will pay dividends. Rotations consisting small grains (wheat, oats, barley, flax and rye) cultivated crops (corn and potatoes) and hay crops, (oats and peas, timothy and clover) are used.

All the labor is done by the farmers with their own horses and machinery, under the direction of the North Dakota Experiment Station. The average net profit of $4.77 an acre at New Salem for the past seven years, and $8.02 an acre at Bathgate for the past six years, justify the methods used.

The North Dakota Experiment Station operates twenty-two other demonstration farms on the same principles, and with similar rotations. These other farms will probably show as good net profits per acre on the average as Bathgate and New Salem have shown. They are operated with the idea of keeping up the soil fertility, and at the same time to pay dividends. They are an object lesson to the farmers in their respective communities, a lesson that is taught from year to year, and which becomes more impressive and valuable as time passes.

79
:35

NORTH DAKOTA
AGRICULTURAL COLLEGE
Government Experiment Station

BULLETIN No. 105

WINDMILL ELECTRIC LIGHTING AND POWER

By Wallace Manikowske

Any farmer, teacher or student in the State may have this bulletin mailed to his address, free of charge, upon application.

FARGO, NORTH DAKOTA. U. S. A.
AUGUST, 1913

Windmill Electric Lighting and Power

BY

WALLACE MANIKOWSKE

A Thesis Submitted for the Degree of
BACHELOR OF SCIENCE
AGRICULTURAL COURSE

AGRICULTURAL COLLEGE
NORTH DAKOTA
1913

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FOREWORD.

The economical use of electricity on the farm for producing light and power has long remained a mooted question. The best evidence in proof of such use of electricity on the farm, however, is the fact that it is being so used. The methods employed and the principles involved are set forth in the following thesis. The purpose of the investigations described herein is to enable the well-to-do farmer to use the windmill and storage battery to furnish the necessary current to light his house and farm buildings; also power to pump water for stock or to charge the pressure tank, grind feed for the farm animals, churn, wash the family clothing, etc., thus dispensing with much of the domestic drudgery and at the same time adding to the farmstead features of considerable interest, especially to the young people.

It is evident that the rural home must be made a desirable place to live and work, and also it must be invested with things interesting as well as useful and labor-saving, if country boys and girls are to be kept on the farm. Electricity, economically generated and safely applied for the purpose of furnishing light and power will go a long way toward making the rural home more attractive, as well as affording an outlet for the exercise of the farmer's ingenuity in applying the power thus generated where it is most needed.

J. H. WORST, Director.

PREFACE.

The use of a windmill for electric lighting and power purposes is possible in almost any part of the United States. A well-designed equipment, together with a 14 or 16-foot windmill, will generate enough electricity to charge a storage battery. By this means current can be used to do the pumping, washing, churning, to separate the milk, and to light a house of sufficient size to accommodate fifteen persons and light all stables and outbuildings necessary for a farm of 1200 acres or more. With a storage battery, it is possible to accumulate a supply of electricity sufficient to extend over periods of atmospheric quiet of from two to ten days' duration, depending upon the size of the storage battery. During periods when the wind blows continuously, as it frequently does in the central states, electricity can be used for ironing, cooking, and many other purposes too numerous to mention. Not only are these things possible but they are an established fact. The windmill electric lighting and power plant described in this thesis is one that has been in successful operation for two years. It has done and is doing all that is herein stated and is usually operated by the women of the family.

Such a power plant will cost but very little more than a gasoline engine electric lighting and power outfit of a similar capacity.

CONTENTS.

- The necessity of electricity upon the farm.
    - To the farmer.
    - To the farmer's wife.
- Attempts to solve the electrical problem.

A successful windmill electric lighting and power plant on the Manikowske Pure Seed Farm, Mooreton, N. D.

- How success came about.
- Difficulties to overcome.
- Structural description.
- Principles to be kept in mind.

Economic value of the windmill as a source of power.

- Power available from a 16-foot wheel in 1912.
- Cost of generating electricity by gasoline and wind power.
    - As taken from various engine companies' catalogs.
    - Cost by wind power, using the same method of calculation.
    - Actual cost per kilowatt.
    - The farmer's attitude toward a windmill.
- Uses of electricity upon the farm.

WINDMILL ELECTRIC LIGHTING AND POWER.

Introductory.

The advent of improved machinery and the adoption of scientific methods in agriculture have been the two principal factors in lightening the burden of country home-keeping. The modern farm and farm home offer, perhaps, the best examples of the rapid increase of conveniences and labor-saving devices that can be had.

Electricity is not necessarily a mere convenience for the use of the opulent who are able to surround themselves with luxuries, but it is proving to be a necessity as a power producing agent in farming and is, beyond question, the most desirable illuminant for the modern farm, both in its economy of generation, for power and in safety of lighting. In spite of the fact that the small gas engine is not as adaptable as electricity to the usual work of the farm, it has long been used to drive the churn, washing machine, pump, and other small machines.

Fig. 1.—The usual daily work of the housewife.

As a matter of economy, the use of electricity in the form of power and as an illuminant in the farm home is very important. There is no reason whatever why the country home should not have as good an illuminant as the city home. On most farms, much time is spent in caring for lamps.

Have the farmers ever stopped to consider how much time is actually devoted to keeping the lamps and lanterns in shape? Supposing it takes but two hours per week to wash chimneys, trim wicks, and keep all lamps and lanterns well supplied with oil, in a year the total number of hours would amount to 104—thirteen days of eight hours each. This would afford an additional two weeks' vacation every year to our housewives, and would mean a much more enjoyable life for them.

The farmers and the residents of the small country towns have long felt the need of electricity. They appreciate the adaptability, the cleanliness, and the convenience of electricity and would gladly adopt it in their homes, if possible; however, they live too far from any central lighting station to be able to buy power at a reasonable cost.

Many attempts have been made to solve the problem by substituting one of the following illuminants: Kerosene, gas, gasoline, acetylene, alcohol, or blaugas. However, electricity has proved to be by far the most desirable illuminant. The gasoline engine, despite the fact that it is neither the most economical nor the most desirable method of generating electricity, is not uncommonly used as a prime mover in many electric plants.

Up to this time, small gasoline engines have been the principal source of power for generating electricity on the farm. Windmill electric lighting has been tried to some extent, but very few successful plants have ever been in operation.

A Successful Windmill Electric Lighting and Power Plant on the Manikowske Pure Seed Farm,

Mooreton, N. D.

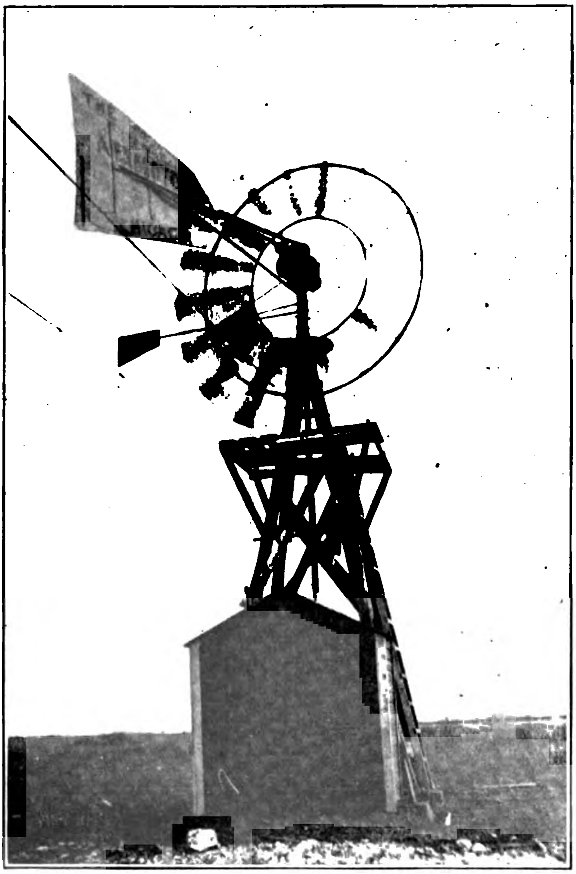

Fig. 2.—Windmill generating enough electricity to light sixty (16-candle-power, 20-watt) lights.

The development of the Manikowske Windmill Electric Lighting and Power Plant has covered a period of eight years. During the first few years of the development of this outfit, all work which had been done by others was reviewed and investigated, but no data of any value was obtainable, even up to the present time. Continuous experimenting, however, has brought about a successful plant which has been in operation for two years. The entire plant, as it exists, was designed by George Manikowske, with the aid of the author.

A windmill electric lighting and power plant requires:

1. A windmill of a size sufficient to develop the amount of power required. In this case, a 16-foot wheel was selected.

2. A speed regulator, the object of which is to so control the varying speed of the mill as to produce a constant speed for generation, even though the load of the generator may be varied.

3. A generator suitable to the amount of power developed by the windmill, and also designed to work together with the governor pulley being used.

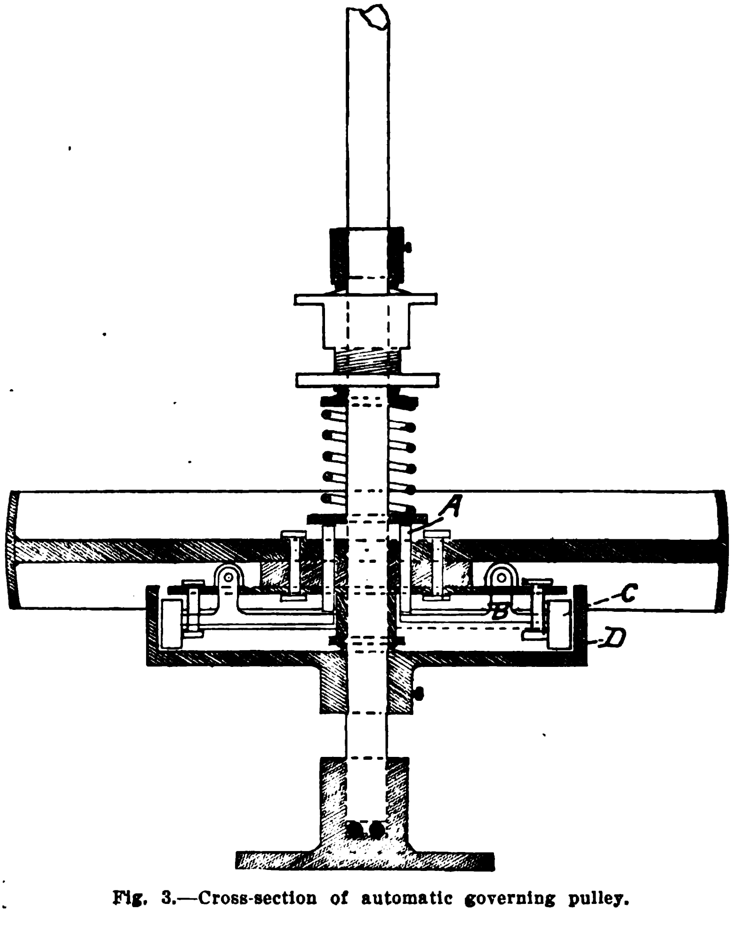

Fig. 3.—Cross-section of automatic governing pulley.

4. A storage battery of a capacity sufficient to store a supply of electricity to be used during calm days. With this outfit, energy might be used from two to ten days without wind, depending, of course, upon the amount of current used and the size of the storage battery.

5. A switchboard conveniently placed and so connected with the apparatus that the entire charging operation is automatic.

Many difficulties were met before success in generation of electricity by wind power was possible; some of which were as follows:

1. The irregular speed of the wheel in different wind velocities.

2. Varying wind currents.

3. Unlike powers produced in different wind velocities.

4. Poorly constructed wheels.

5. The necessity of a device which would work as a check valve, permitting the electricity to flow into the battery and retaining it there until required for use.

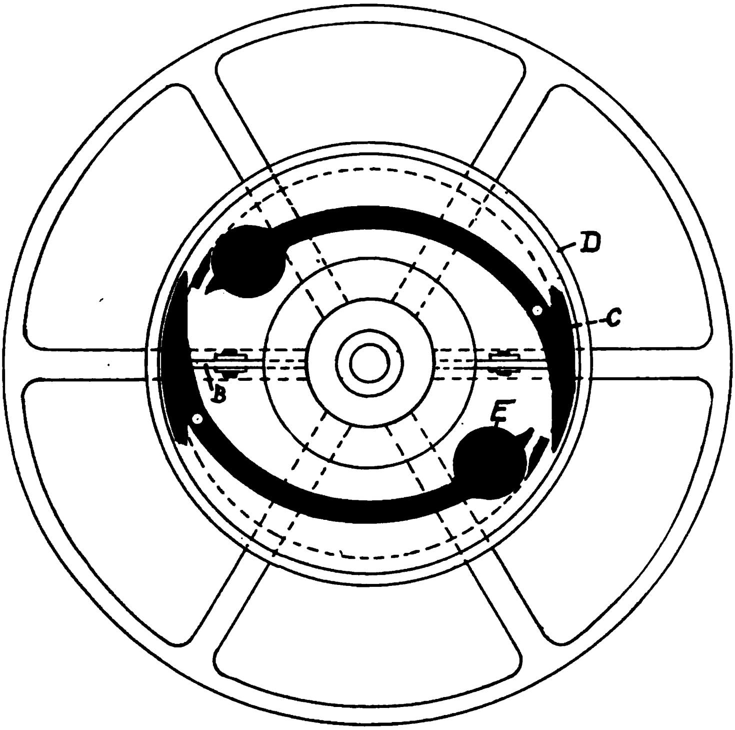

Fig. 4.—Governing pulley, showing friction shoes.

6. An automatic self-regulating switchboard which is economical of current.

7. A practical method of storing electricity for several days.

After a number of experiments, and years of work, the first three difficulties were overcome by the use of an automatic governing pulley which would not allow the generator to travel above a certain predetermined speed. Figure 3 and Figure 4 show the governor pulley in detail.

Figure 3 is a cross section, while Figure 4 is a top view. The weighted arms which are shown in black (Figure 4) are fastened to the belt wheel which drives the generator. The friction drum "D" is fastened to the windmill shaft. This, then, travels at a variable speed. The pulley to which the friction shoes are fastened is not fastened to the upright shaft, and only when the shoes bear on the friction drum will this pulley revolve with the shaft.

In Figure 3, the spring which presses against the pin "A" in turn pushes down on lever "B", which tends to push the friction shoe "C" up against the friction drum "D". As the speed of the friction drum increases the pulley speed also increases until it.gets to a point where the centrifugal force, acting upon the weights "E" (Figure 4) will cause it to fly out and thereby release the shoes from friction drum, which allows the shaft to travel faster than the driving pulley. This in turn allows the wind wheel to travel faster, permitting the excess wind to pass through the wheel without doing work.

As the windmill speed decreases, the friction shoes will again be placed in the original position, bearing upon the friction drum "D". As the centrifugal force of the weights is overcome by the tension spring, pressure is applied to pin "A", acting upon lever "B", forcing the friction shoes outward and bringing the weights near the center of the wheel. Where the generator load was constant this device gave constant speed for charging the storage battery. However, when a variable load was taken off, the speed regulation was not the best, making it desirable that an improvement should be made. This was brought about a short time ago by modifying the first governor pulley (Figure 3). This new governor pulley gives constant speed to a variable load from the windmill shaft which travels from 0 to 500 revolutions per minute.

By this method the storage battery is protected from becoming charged too rapidly, the generator also being protected against excessive speeds which would tend to cause the windings of the armature to leave their respective slots.

The fourth difficulty was overcome by selecting an efficient wheel which should have been mounted on a high tower. A force feed oiler, such as is used for automobiles, was placed on the head of the mill in such a manner that, when the wheel revolved, its bearings were automatically oiled.

The next and probably the most important point was the building of an automatic cut-out and cut-in, which would work on the difference of potential (voltage), between the generator and battery, it being so positive that one could rely upon it with absolute certainty. Much of the successful operation of this plant depends upon this little device which makes practically an automatic fool-proof switchboard a reality.

The storage battery in its improved form has made possible a reservoir for storing electrical energy. By the use of the storage battery, light and power do not depend directly upon the wind; as sufficient current can be generated and stored during windy days to be used during periods of calm.

The windmill in question consists of a 16-foot wheel, mounted on a 20-foot tower, which is located 1500 feet from the nearest building. (Cover page.)

This distance was made necessary because of the entire farmstead being surrounded by a tall grove. Had the wheel been on a 50-foot tower, there probably would have been fifty per cent more power available. On the other hand, had the mill been located in the center of the farmstead, it would have been necessary to erect a 100-foot tower, so that the velocity of the wind would not be retarded by the tall trees. A cheap shed covers the generator and governor pulley. There is no need of heating this shed during any part of the year.

At right angles to the wheel's axis and the large vane is attached a smaller vane which serves as a governor and throws the mill out of the wind when too great a wind velocity is reached. If the wheel is turned into a gale or into wind of too great velocity, the small vane will at once be acted upon and will tend to lessen the wind exposure by turning the wheel out of the wind. This mill as it was originally designed was set off center, but even with the additional vane that has been added, the speed is rather irregular, making a governor pulley (as already described) essential to the successful operation of the plant. This pulley drives the generator through a quarter-turn belt, running over an idler pulley. (Figure 5.)

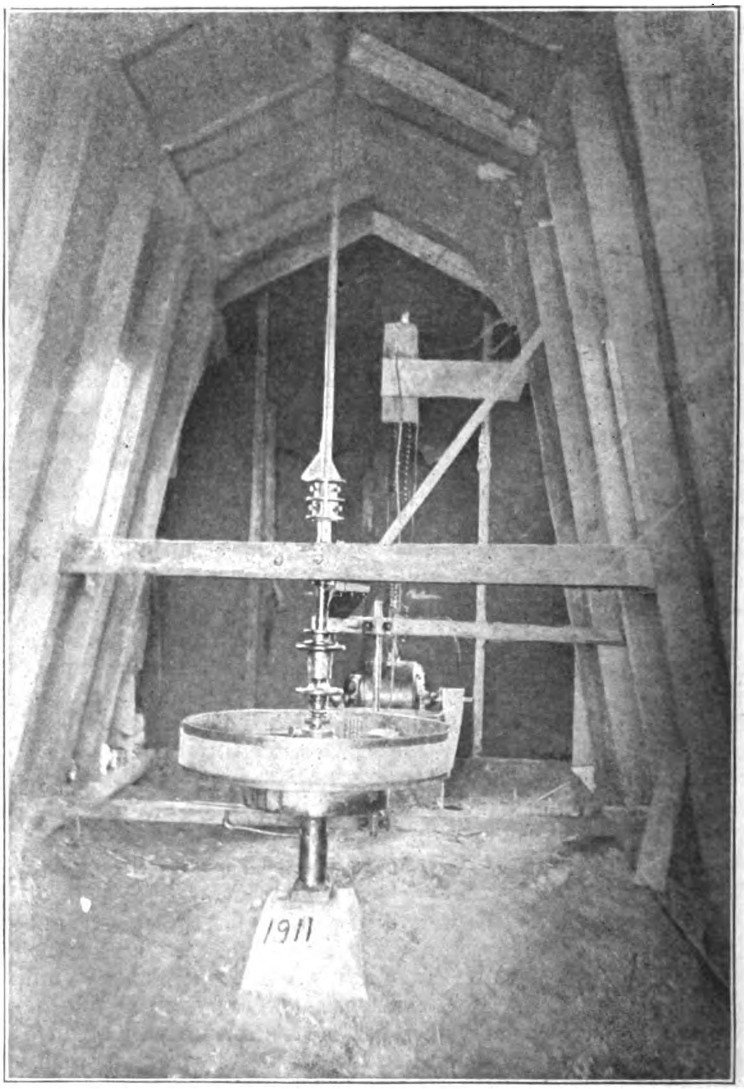

Fig. 5.—Photograph showing power house, governor pulley, and generator in the rear.

From the illustration, it will be noticed that no foot or bevel gears are used, thereby obtaining the greatest efficiency possible.

The generator is a one and four-tenths kilowatt, one hundred fifty volt, 1800 revolutions per minute, special wound, self-regulating machine designed to work with the governor pulley.

It is controlled from the switchboard which is located in the kitchen of the house. (Figure 6.)

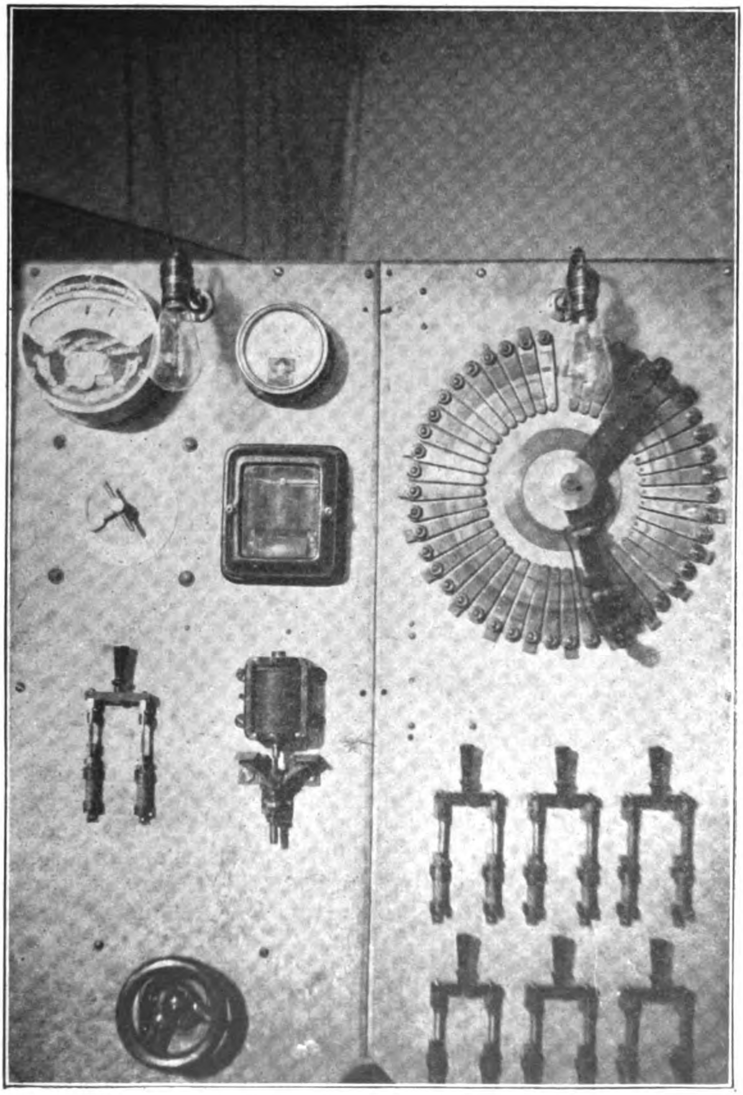

Fig. 6 Switchboard

The current passes over a copper wire to the switchboard, then passes through the automatic cut-out and cut-in and into the battery. The entire plant is controlled from the board—the windmill being started and stopped by a crank which winds up a wire on a drum. In the upper left-hand corner of Figure 6 is the voltmeter which indicates the amount of current stored and available in the battery. It also tells what pressure (voltage) should be put upon the lighting curcuit.

The small, clock-like indicator on the switchboard is the ammeter, which shows how much current is being used from the battery, and also how much from the generator. This approximately tells the number of lights burning, even though they cannot be seen. Below the ammeter are the two instruments which compose the automatic cut-out and cut-in—this being the part of the switchboard which makes it almost entirely fool-proof. Whenever the generator is running at a speed great enough to produce a voltage which will exceed that of the battery, then the automatic cut-in will connect the generator on the battery line and begin charging the battery. Again, when the generator voltage decreases below that of the battery, the automatic will disconnect the generator from the battery line and will not permit the electricity already stored to be discharged. When the generator switch is in and the windmill standing still, this cut-out uses a small amount of electrical energy. To overcome this, the author, with the aid of his brother, has designed and tested out eight cut-outs and cut-ins since the one described has been in operation. The results obtained show that a much simpler cut-out and cut-in gives better satisfaction in that it acts quicker and uses practically no energy from the battery to be operated. Today a much simpler and cheaper switchboard is a reality.

The hand wheel on the bottom of the left hand panel is the rheostat which is used to adjust the charging rate of the generator. Above this is the hand switch which cuts the generator off the the entire switchboard. With the new cut-out, this switch is not necessary, as the automatic operates a similar one, no attention being required to cut the generator on or off the switchboard line. Above this unnecessary switch is the voltmeter switch, making it possible to read the voltage of any of the end cells, also that of the generator and battery. The large circular dial on the right panel is the end-cell switch. By the use of end cells, any desired voltage may be obtained, giving the lights any degree of brightness that is desired; also keeping up the voltage of the battery through the state of discharge. One of the arms is the charging arm, while the other is the discharge arm. This makes it possible to charge the battery at the same time the current is being used. For instance, if one is using a flatiron which takes five amperes and the mill is able to deliver only two amperes, because of lack of wind, then three am-

Fig. 7.—The electric flat iron in use.

peres would come from the battery and the mill would be furnishing the two amperes.

However, if a wind should come up which would produce enough power to deliver seven amperes, then five

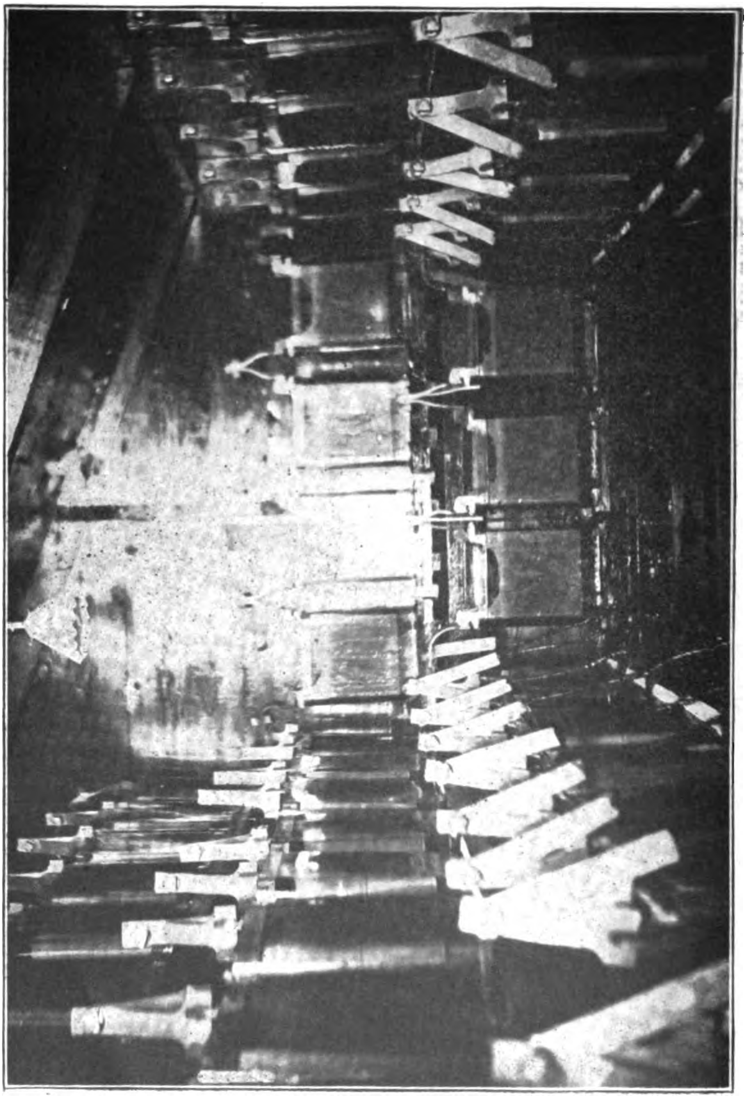

Fig. 8.—Storage battery, which is used to supply electricity for several days without charging.

would go to the flat iron while the other two would be stored in the battery. The entire operation in this case is automatic in every respect, giving one the opportunity to utilize every possible wind, (except when below a certain number of miles per hour.) Below the end cell switch are the six service switches, one each for the house, barn, elevator, blacksmith shop, and arc lamp, and the other being used for charging small automobile storage batteries.

The storage battery is located in the attic of the house. It is a sixty-two cell, forty ampere hour, 110-volt Plante type battery.

Its capacity in sixteen candle power Tungsten twenty-watt lights is as follows

220 hours for one lamp.
110 hours for two lamps.
22 hours for ten lamps.
10 hours for 22 lamps.

If eight candle power lights were used, the same energy would give twice the number of lamp hours, as indicated above.

The plant is so arranged that any or all of the sixty-five lights and the arc light may be used at the same time. However, there is little occasion for all of the lights to be used at the same time. As a rule, more electricity is used during the winter months than during the summer months, which makes it necessary to supply more current to furnish sufficient energy. Moreover, records show that a greater wind movement is invariably at hand during the winter months and as a rule much more current can be produced, thereby furnishing the required amount of electricity to light the home during the long winter nights.

The method of operation is very simple, even with the old switchboard, in that all that has to be done is to wind up the windmill wire which puts the mill in gear and then throw on the generator switch. The automatic current regulator and governor pulley takes care of the irregular speed, making the entire charging process automatic.

Power of Windmills.

Figure 9 shows a power *comparison of three modern 12-foot wheels of different construction.

When the wind is blowing ten miles an hour, mill No. 1, which is a wood wheel having 96 sails, produces .05 horse

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*All brake tests taken from U. S. Irrigation and Drainage Paper No. 42 by E. D. Murphy.

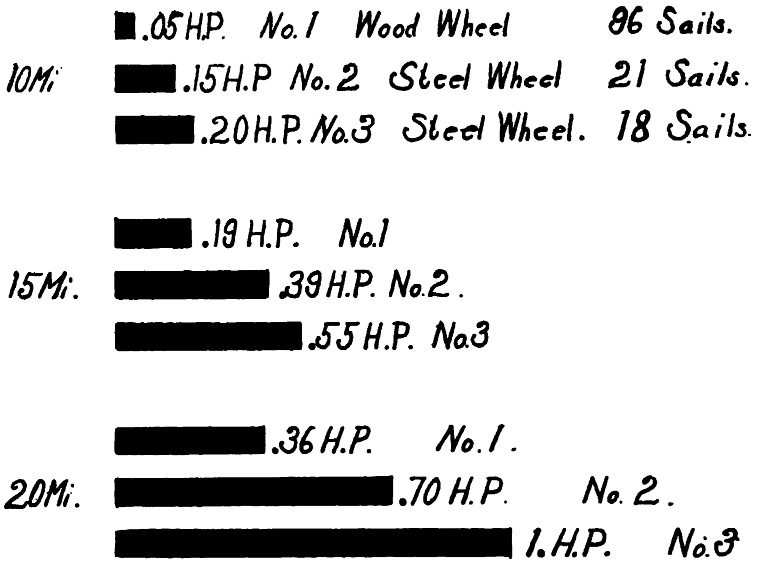


Fig. 9.—Power comparison of three modern 12-foot windmills.

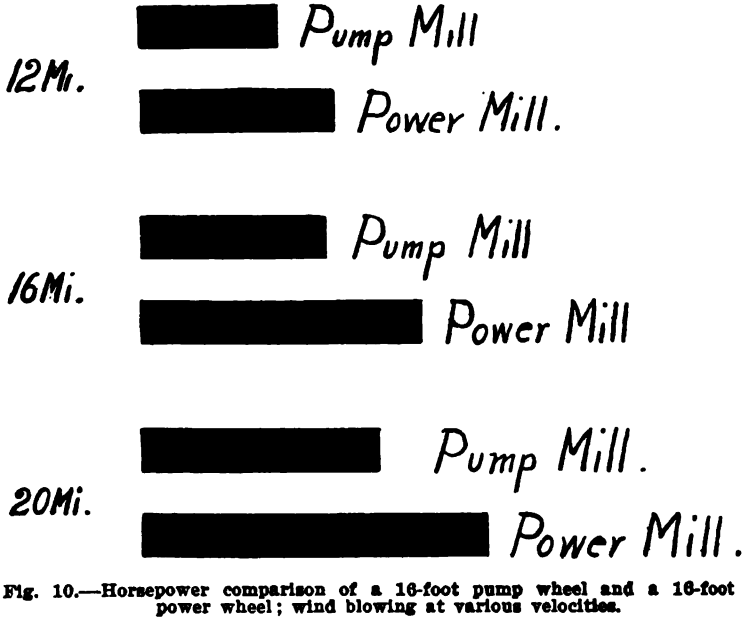


Fig. 10.—Horsepower comparison of a 16-foot pump wheel and a 16-foot power wheel; wind blowing at various velocities.

power; while No. 2, a steel wheel with 21 sails, produces three time as much power, or .15 horse power; and No. 3, having but 18 sails, produces four times as much power as does the wood wheel. The same ratio is approximately kept throughout the various wind velocities.

Professor Murphy gives figures showing that a power mill is more efficient than a pump mill, as is shown by Figure 10.

A pump mill is not as efficient probably because of the fact that its power is delivered in jerks or strokes. The efficiency of various types of wheels should always be taken into consideration before installing a windmill of any kind.

Figure 11 will show the number of hours a 16-foot mill must run, utilizing various winds, to store up enough electricity to light ten sixteen-candle-power lights for five hours.

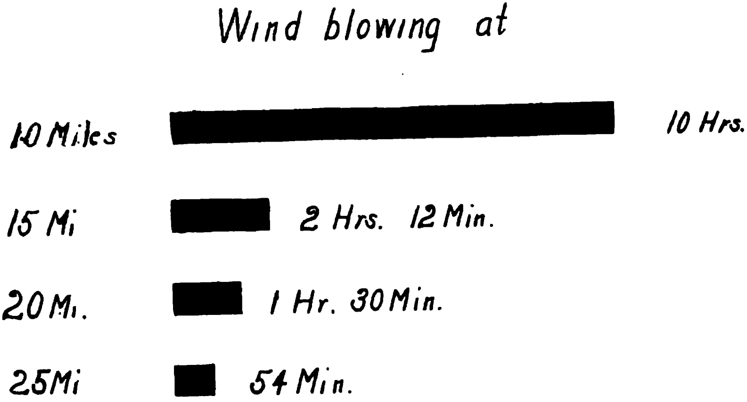
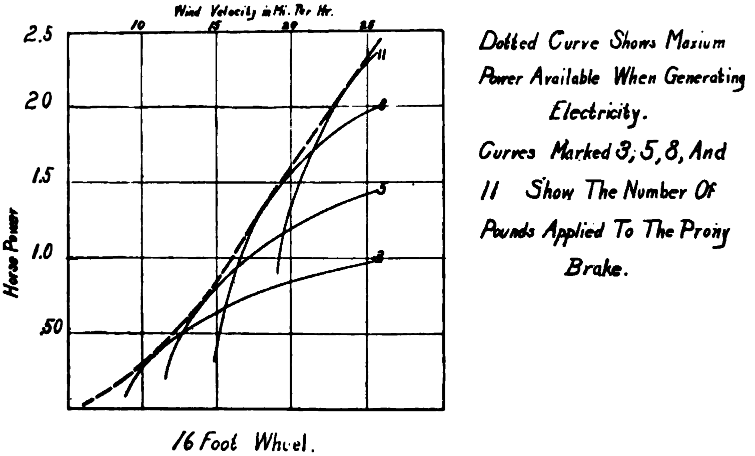


Fig. 11.—Number of hours a wind must blow (at various velocities) to store enough electricity that will light ten lights for five hours.

If the wind was blowing but ten miles per hour, the mill would have to run ten hours to store up enough electricity to light the ten lights for five hours. But should the wind velocity change to fifteen miles per hour, then the same amount of current would be produced in two hours and twelve minutes. Again, with a twenty mile wind, the same current could be produced and stored in fifty-four minutes. The maximum value of winds over twenty-five miles per hour can only be utilized through the use of a large storage battery, because of the fact that battery capacity determines the charging rate.

Windmills are better adapted for generating electricity than they are for any other purpose, because the load increases directly as the speed of the generator or wind velocity increases.

Figure 12 shows various loads applied to the Prony brake of a 16-foot mill. The curves marked 3, 5, 8 and 11 indicate the respective pounds applied to the Prony brake. Taking the curve 3, it will be noticed that at eight miles per hour the wheel began to revolve, using about one-tenth horse power; its maximum power at twenty-five miles per hour was approximately one horse power. Curve 5 shows that two-tenths of a horse power was used to start the wheel and the maximum power at twenty-five miles was approximately one and four-tenths. The curve marked 8 uses three-tenths horse power, starting to revolve in about a fifteen mile wind, developing a maximum power of one and nine-tenths horse power at twenty-five miles per hour. In the last case, where eleven pounds were applied to the Prony brake, no power was produced before a wind velocity of eighteen and a half miles per hour was reached, or nine-tenths horse power being used to start the load—the maximum power in this case being two and three-tenths horse power at twenty-five miles per hour.



Dotted Curve Shows Maxium Power Available When Generating Electricity.

Curves Marked 3, 5, 8, And 11 Show The Number Of Pounds Applied To The Prony Brake.

Fig. 12.—Curves showing adaptability of windmills for generating electricity.

It is very evident from these figures that the load of a windmill must increase in direct proportion to the wind velocity, if maximum efficiency is desired. In this case, the maximum power of a windmill is shown by the dotted curve which is drawn tangent to the most efficient points of the variable load points of the variable load curves. The length of the dotted curve or the amount of power that is actually sable is determined by the charging rate of the battery. xcessive charging rates at intervals are taken care of by he governor pulley.

The following points must be kept in mind before a windmill electric lighting and power outfit is made a success:

1. A good wind velocity (20 miles per hour) must be at hand at least on an average of six hours during every week.
2. The erection and use of an efficient mill.
3. The necessity of a device which would work as a check valve, permitting electricity to flow into the battery, but not permitting it to go out, when the wind stops blowing. The automatic cut-out and cut-in must be ready for operation at any time and should not have any coils in circuit with the battery when not in use.
4. An automatic, self-regulating switchboard.
5. A practical method for storing the energy several days.

Economic Value of the Windmill as a Source of Power.

It is practically impossible to estimate the probable power that a 12 or 16-foot mill might develop during a certain time, unless accurate records are kept.

In estimating the available power that may be derived from such mills, use was made of the U. S. wind velocity tables maintained by the Department of Chemistry at the Agricultural College which gives the actual wind movement for this year (1912) at Fargo, N. Dak.

The following table shows the mean number of hours per month that the wind velocity was 0 to 5, 6 to 10, 11 to 15, 16 to 20, 21 to 25, 26 to 30, 31 or over miles per hour at Fargo, N. Dak., for 1912; also the mean horse power of a 12 and 16-foot mill for each month. The number of horse power hours* for each mill, each month, is also given. The horse power hours for any month is found by multiplying the number of hours by the horsepower and adding the products.

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* A horse power hour is considered to be an equivalent of one horse power for *one hour*.

AVERAGE WIND MOVEMENT AT FARGO.

1912.

Month	0-5 Miles Hours	6-10 Miles Hours	11-15 Miles Hours	16-20 Miles Hours	21-25 Miles Hours	26-30 Miles Hours	30— Miles Hours	Total Hours	Horsepower Hours 12-ft. Wheel	Horsepower Hours 16-ft. Wheel
January	127	285	130	76	47	39	28	732	352.4	510.0
February	76	145	229	105	83	40	18	696	433.7	627.1
March	44	212	270	106	68	26	18	744	408.8	585.9
April	62	142	129	132	130	59	66	720	621.0	1009.5
May	75	119	150	211	104	31	54	744	574.4	939.1
June	54	171	223	179	53	—	40	720	417.4	602.9
July	220	177	184	117	25	21	—	744	271.1	388.5
August	211	251	141	91	44	6	—	744	232.8	332.3
September	152	148	231	95	34	48	12	720	381.5	524.4
October	145	91	268	116	51	24	49	744	442.7	638.8
November	87	141	262	180	29	20	1	720	358.4	514.2
December	42	185	178	162	96	30	39	732	506.0	735.6
H. P. of 16-ft. mill		.13	.56	1.25	2.0	3.15				
H. P. of 12-ft. mill		.10	.41	.85	1.36	2.13				
Total Horse Power Hours									5000.2	7408.3
Average Horse Power Hours Per Month									416.7	617.4
Average per Day									13.6	20.2

The work done by these mills is greatest at this place in April (621 horse power hours for the 12-foot and 1009.5 for the 16-foot) and least in August (232.8 horse power hours for the 12-foot and 332.3 for the 16-foot). The mean or average monthly power is 416.7 for the 12-foot mill and 617.4 for the 16-foot mill. Stating this fact in another way, it might be said that a 12-foot mill at Fargo, N. Dak., would furnish on the average 1.36 horse power for ten hours every day of the year, while a 16-foot mill would furnish on an average 2.1 horse power for ten hours each day in the year. This power may not be possible every year and very often much of it is developed during a single month, making it necessary to have an exceptionally large battery to utilize all the power that may be developed. However, the total wind movement per year is fairly constant and one has reasonably good grounds upon which to expect as much as is indicated. The following figures given by the Bismarck Weather Bureau, North Dakota, will show the variation of total wind movement over a series of years:

1912—89,222 mi.
1911—94,251
1910—94,897
1909—94,249
1908-101,619
1907—90,542
1906—96,181
1905—88,673
1904—91,009
1903—89,793
1902—83,927
1901—85,897

It is very hard to try to draw definite conclusions from the average wind velocity as given, but the map will bring out comparisons between different sections of the United States.

The following map of the United States (Figure 13) taken from the Agricultural Year Book for 1911 will give one an idea as to the economic use of the windmill in various sections of the United States.

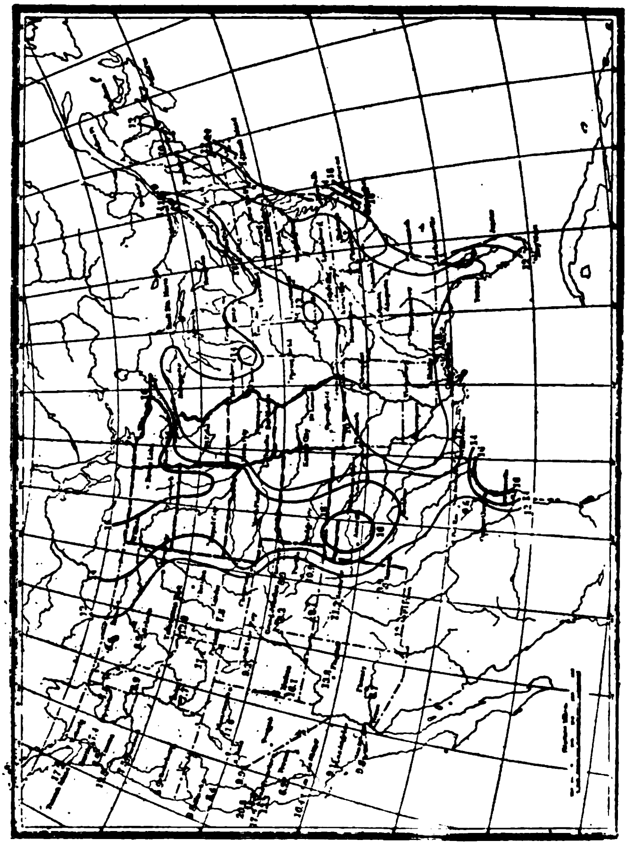

Fig. 13.—Average hourly velocity of the wind at 3:00 p. m., local standard time, the approximate hour of greatest wind movement.

Cost of Electricity.

The next point for consideration is the probable cost of producing electrical energy by wind power, compared with other methods of generation. Therefore, a first-class gasoline engine electric lighting outfit was selected, of sufficient capacity to produce as much current as was able to be produced by a good windmill, in the year 1912. Many farmers are misled on the cost of generation by various gasoline engine companies because of the fact that the data is selected from catalogs of these companies.

The following is a comparison of producing electrical energy by gasoline power and wind power, founded upon the same facts as taken by various gasoline engine electric lighting companies.

A good gasoline engine would develop one horse power for one hour with one and one-fourth pints of gasoline. Therefore, 1,000 watts or one kilowatt (1,000 watts or about one and one-third horse power) can be produced for one and one-third times one and one-fourth pints, which is one and seven-tenths pints.

With gasoline at $ .15 per gallon, this would make a cost of $ .034 per kilowatt.

Putting the generation of electricity by wind power on the same inconsistent method of figuring, it is very evident that **electricity would cost absolutely nothing at all.**

However, let us make a more accurate comparison, taking into consideration every detail and giving the actual cost of generation by gasoline and wind power, where electricity is produced in a similar manner.

The following data takes all practical points into consideration. The interest and depreciation upon the wiring and fixtures of the plant is omitted, as it would be the same in both cases and besides it is very hard to give any accurate data, as conditions are different upon almost every farm.

Cost of Generating Electricity By Gasoline Power

Size of Engine in H. P.	4
Cost of engine complete	$220
Cost of housing	$200
Horsepower hours produced	7,408.3
Horse power hours per day	4

Cost of Generating Electricity By Wind Power

Size of wind wheel	16-ft.
Cost of windmill complete including governor pulley	$200
Cost of housing	$35
Average horsepower hours per year (1912)	7,408.3
Average horse power hours per day (10 hours)	2.1

Expense of Power Per Year.

Interest on first cost at 6 per cent	$25.20
Depreciation at 5%	21.00
Cost of heating	20.00
Attendance 1/5 time at 20c per hour	73.20
Lubrication oil, ¾ pints for 5 hours at 50c per gal.	17.16
Gasoline, 1¼ pts. per horsepower hour at 20c per gal. (Evaporation and waste should be considered)	231.50
Total	$388.06

Interest on first cost at 6 per cent	$14.10
Depreciation at 5%	11.75
Cost of heating	——
Attendance 1 hr. per week at 20c per hour	10.40
Lubrication oil 1 pt. per week at 40c per gal.	2.60
Total	$38.85

Average number of watts per day recovered from dynamo 80% efficiency	12,079.90

Average number of watts per day recovered from dynamo 80% efficiency	12,079.90

Expense of Generating Electricity.

Cost of dynamo	$140.00
Interest on first cost at 6%	$8.40
Depreciation at 5%	7.00
Oil, 3 gal. at 80c	2.40
Total	$17.80

Cost of dynamo	$110.00
Interest on first cost at 6%	$6.60
Depreciation at 5%	5.50
Oil, 3 gal. at 80c	2.40
Total	$14.50

Average watts recovered from accumulators per day efficiency 75%	9,059.90
Average number of 16-candle power 20-w. lights that could be used 4 hours per day	113.20
Probable size of battery to be used, amp. hrs.	30
Cost of storage battery, 110 volt	$300
Cost of switchboard	$125

Average watt hours recovered from accumulators per day efficiency 75%	9,059.90
Average number of 16-candle power 20-w. lights that could be used 4 hrs. per day	113.20
Probable size of battery to be used, amp. hrs.	80
Cost of storage battery, 110 volt	$550
Cost of switchboard	$150

Expense of Storing Electricity.

Interest on first cost at 6%	$25.50
Depreciation of battery at 12%	36.00
Depreciation of switchboard at 5%	6.25
Attendance 8 hours at 20c per hour	1.60
Total	$69.35

Interest on first cost at 6 per cent	$42.00
Depreciation of battery at 12%	66.00
Depreciation of switchboard at 5%	7.50
Attendance 12 hours at 20c per hour	2.40
Total	$117.90

Total cost of generation per year	$475.21
Cost per lamp hour	.00286
Number of 16 candle-power lights that could be used one hour for 1c at above rate	3.4
Cost per kilowatt	$ .1433
If current was sold at 15c per kilowatt it would bring	$497.38
Net gain	22.17
Interest on investment by having a gasoline engine electric lighting outfit	2.2%

Total cost of generation per year	$171.25
Cost per lamp hour	.00103
Number of lights that could be used one hr. for 1c at above rate	10
Cost per kilowatt	.0516
If current was sold at 15c per kilowatt it would bring	$497.38
Net gain	$326.13
Interest on investment by having windmill electric lighting outfit	31.2%

The cost of a kilowatt by wind power is then but five (5) cents, while if it were produced by gasoline engine it would cost almost three times as much, or 14.3 cents per kilowatt.

The initial cost of the two outfits is practically the same.

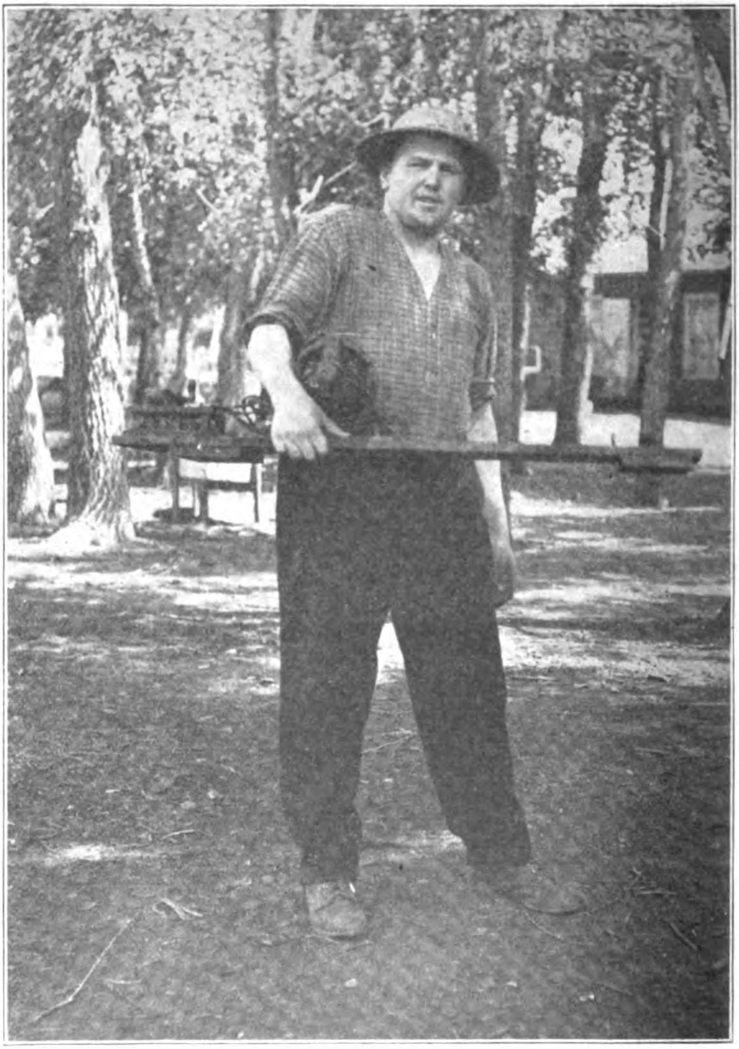

Fig. 14.—Carrying ¾ horse-power portable motor which displaces two small gasoline engines.

Should the current be sold at 15 cents per kilowatt, there would be a net income of 10 cents for every kilowatt sold from the wind power plant, and only .7 cent from the engine outfit. Or, in other words, if the money were invested in a windmill outfit, it would bring an income of 31.2 per cent above the 6 per cent already figured in as interest on the investment, while with the engine plant an income of but 2.2 per cent is realized.

For a permanent power the windmill is far cheaper than any other power except possibly that of water. The author has written to a number of windmill owners, asking various questions concerning their mills in order that he might get the farmer's viewpoint of the windmill; also to find out why windmills are not more generally used. Seventy-five replies were received. The following questions were asked. A favorable conclusion can be drawn.

Does the windmill wear well? 73 replied Yes; 2 replied No.

Does it govern well? 49 replied Yes; 15, Fair; 6, No; 5 did not say.

What make of mill have you? 63 were pump; 12 were power.

What is the upkeep per year? The answers here varied considerably—all the way from nothing at all to $2 per year; one reported $5 per year and another $6.

In the general remark column, almost every owner made the remark that he was satisfied with his mill, and that wind power was far cheaper than gasoline engine power. However, where an objection was raised, it was because of the uncertainty of having power when wanted. Wherever a storage tank was used in connection with the mill, the owner was well satisfied in every instance.

Since electrical energy can be made available to the farmer of average means for little or nothing, after the plant is once installed, the farm will become a place of social relaxation and will serve as a summer resort as well as a place of business. It will be possible to have an abundance of light throughout the house. Electricity can be made to do the pumping to supply water for the heating tank or for any other place; electric fans would lessen the extreme warmth of the summer, for there is nothing more comfortable for the men and women who have been toiling all day in the summer heat than the cool, refreshing breeze of an electric fan.

The housewife's labor will be lessened very materially by the use of a bread mixer, potato peeler, dish washer, and by electric stoves, hot plates, hot pads, water and milk heaters, curling irons, massage machines, hair driers, coffee percolators, chafing dishes, and vacuum cleaners.

In the creamery, a motor could easily be arranged to run the cream separator, churn, butter worker and the milk tester. Electricity also could be used to pasteurize the milk, manufacture ice and freeze the ice cream.

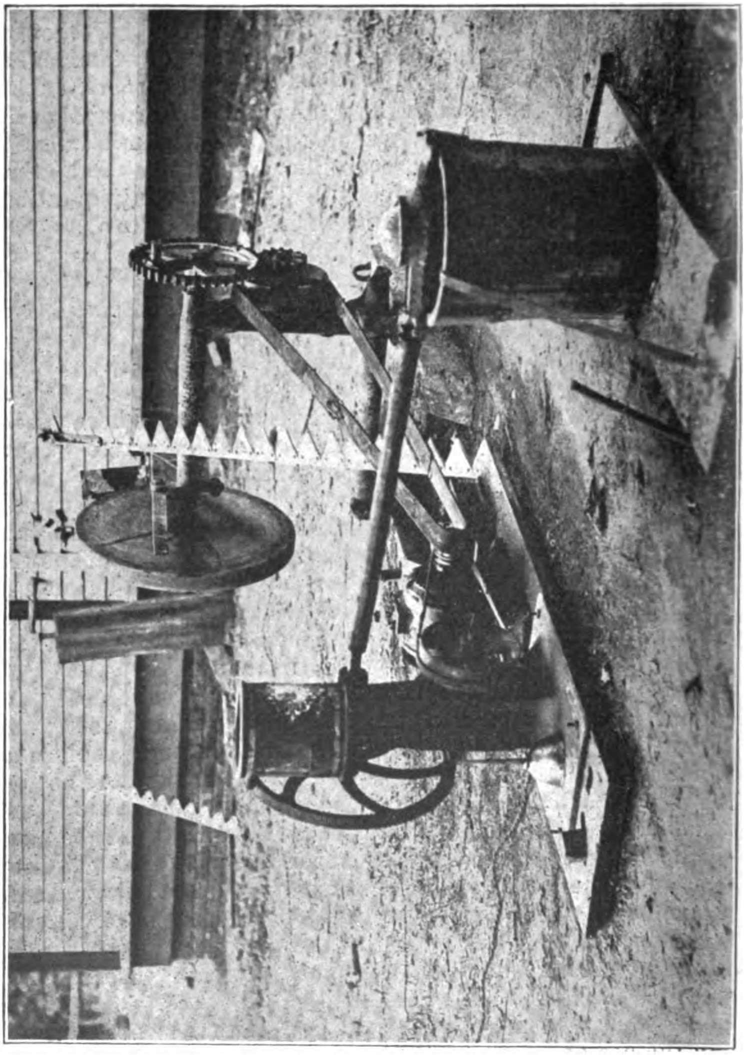

Fig. 15.— Electric motor freezing ice cream and turning the grindstone.

Probably the housewife would next consider the laundry equipment the most important. There is no other source of energy so adapted to laundry work as is electricity. The drudgery of the wash-day is done away with when one is not compelled to turn a washing machine.

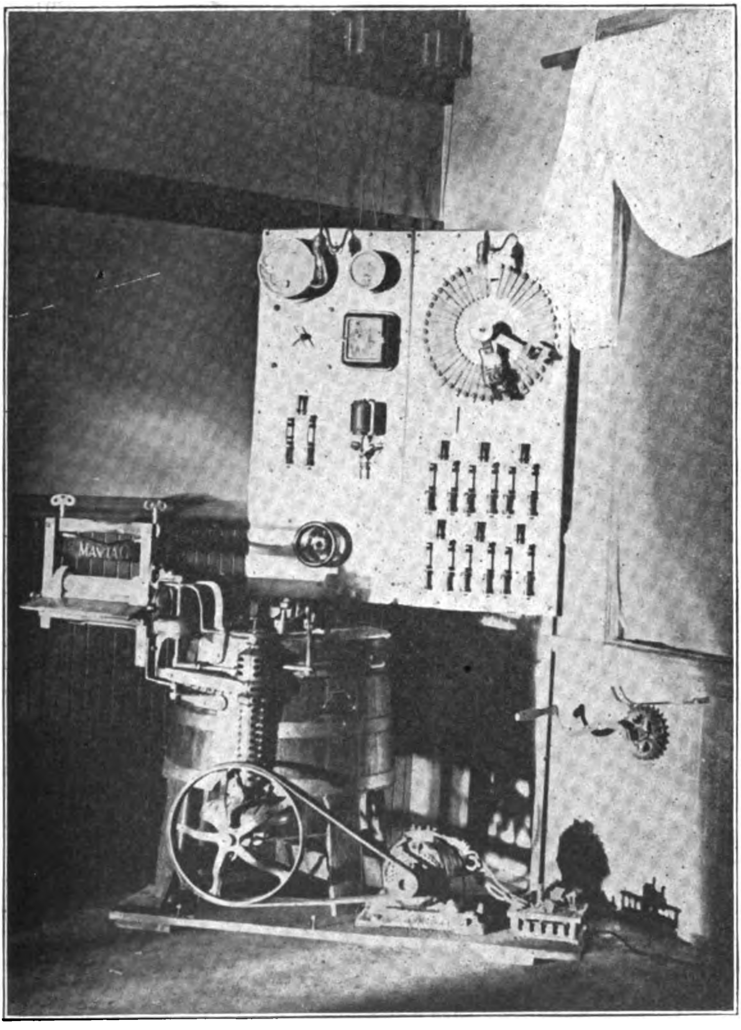

Fig. 16.—Washing machine ready for operation.

The mangle and electric flat iron (Figure 7) are great labor-saving devices. No woman who has used these advantages can be induced to give them up.

Fig. 17.—A lantern may be the cause of a fire at any moment.

Electricity on the farm not only lessens the drudgery for poor old mother, but helps every individual and department. Think of the number of fires which occur every year, because some lantern happened to be tipped over in the barn.

—Too often lanterns are hung on unreliable nails in places where, if a horse should happen to upset one, the result would be the burning of the barn. There is but one solution to this problem; that is the use of electricity, and motors can be used in the barn for running the clipper, feed elevator or the milking machine. Electricity might still be used for various other important duties upon the farm, such as cleaning grain, in the shop for running the forge, drill press, emery wheel, grindstone (Figure 15), turning lathe, trip hammer, for electric welding, and for vulcanizing automobile tires.

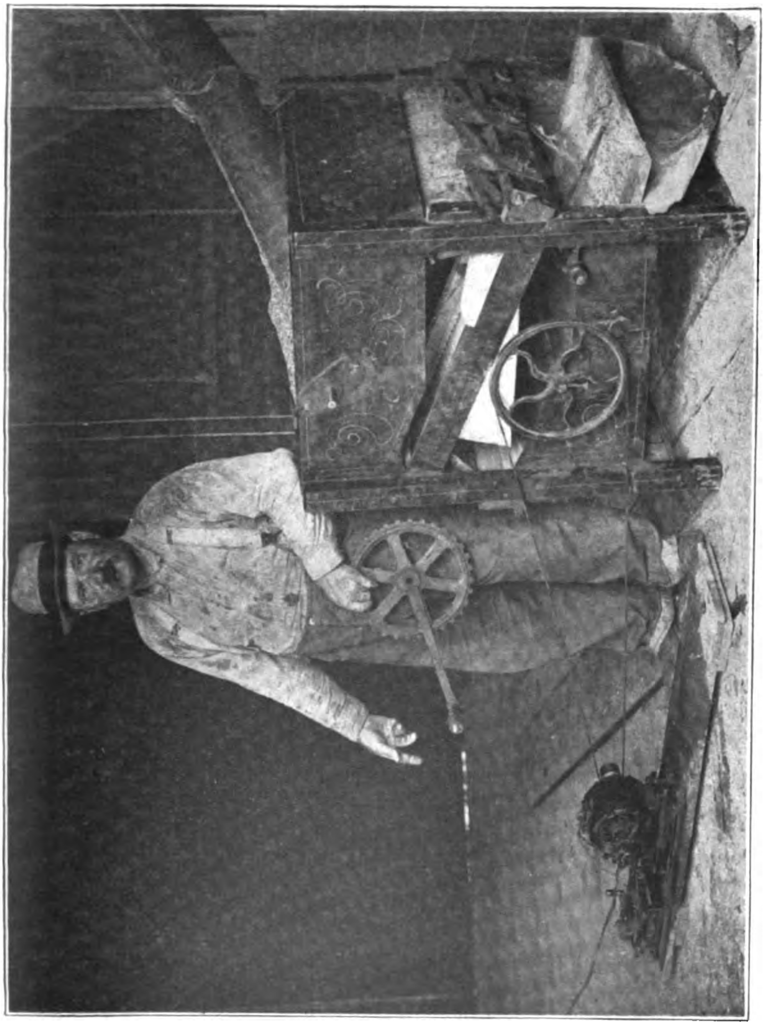

Fig. 18.—Crank removed. showing motor cleaning grain.

The entire farmstead could be lighted by means of arc lamps.

It is possible to utilize electricity for all these conveniences where a sufficiently large windmill is used with a correspondingly large storage battery.

A farm so equipped makes country life a pleasure. It helps solve the labor problem and makes the boys and girls love rural life.

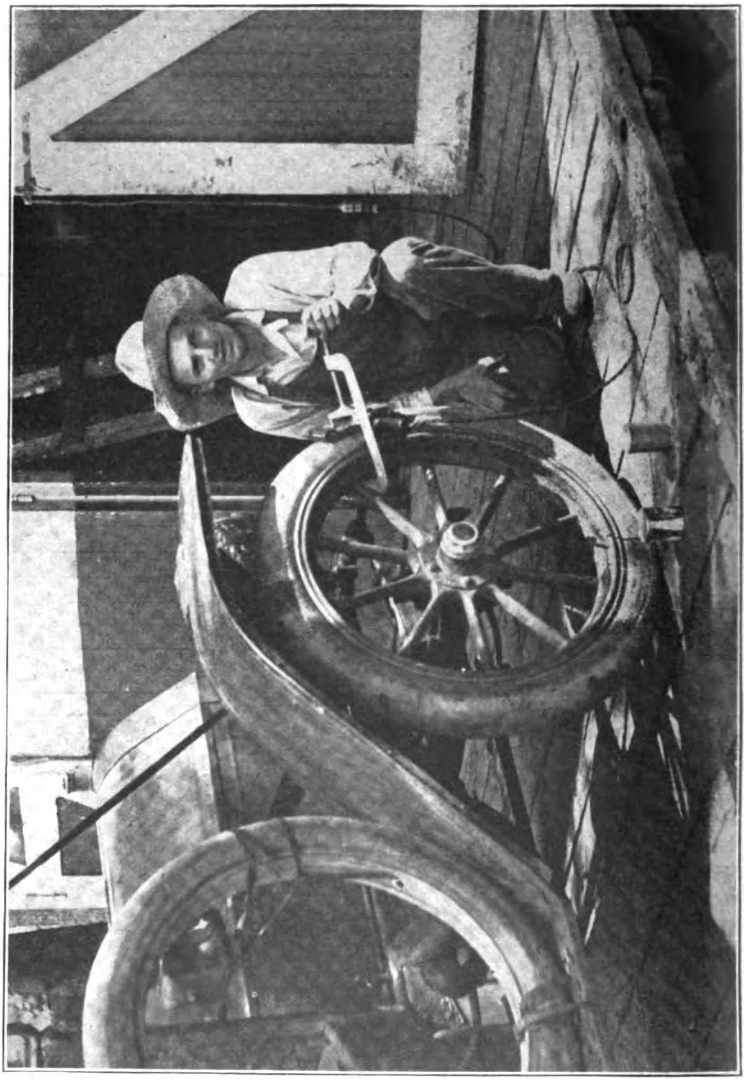

Fig. 19.—Photograph showing how electricity is used for vulcanizing automobile tires.

The following illustration shows the attitude taken by many of our bankers where the farm is not only a place of business but an ideal home as well.

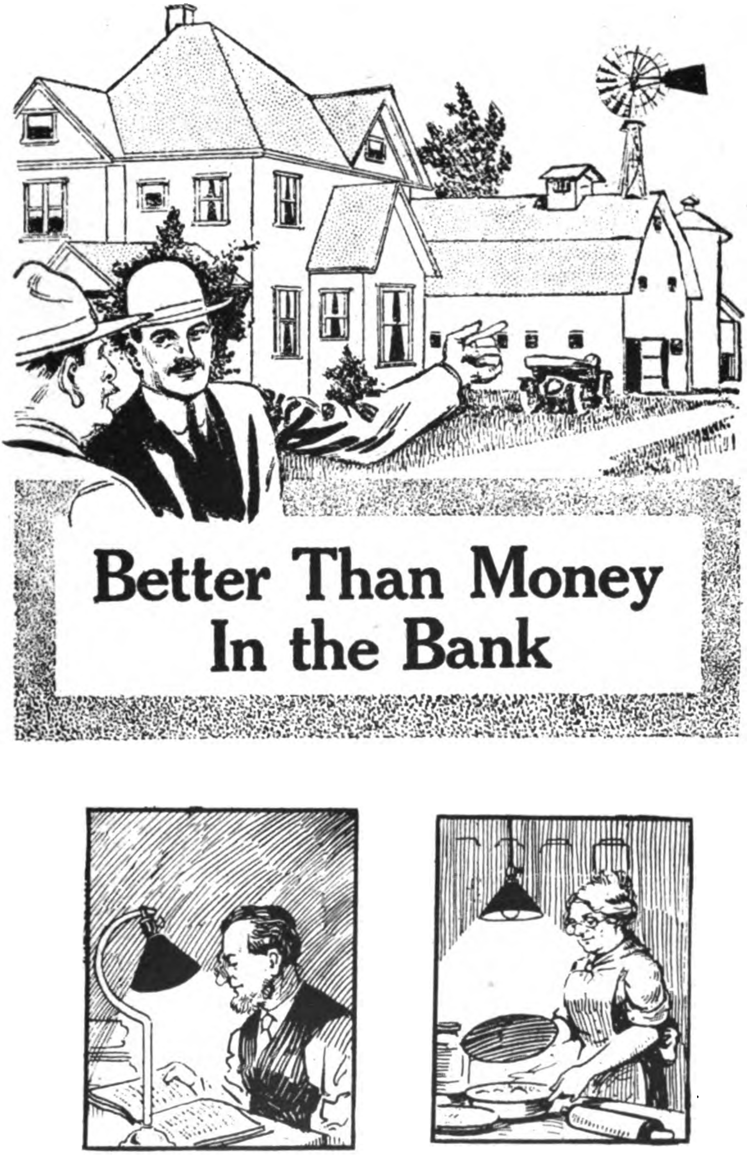

Fig. 20.—The banker's attitude toward improved farms.

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3. The Distribution of Prussic Acid in the Flax Plant. By J. W. Ince.
4. Influence of Bran Extract on the Baking Quality of Flours. By H. L. White.
5. Phosphorous Content of Wheat and Flour and Its Relation to the Baking Qualities of Flour. By H. L. White and R. F. Beard.

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OCTOBER 1913

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INTRODUCTION.

Two important lines of study have been carried on during the past two years or more in this Department, and some of the results now completed are ready for publication; one line with regard to flax products and the other with regard to wheat and flour investigations.

The flax products are considered under three heads: The Fertility Constituents of Flax, or, an attempt to show to what extent the elements of fertility are removed by flax as compared with other farm crops; Investigation of the Feeding Value of Flax Material as Determined by Chemical Analyses, giving the results of investigations not only upon flax itself but upon flax screenings, chaff and other by-products, and shows to what extent these products are being utilized by manufacturers of various feeding stuffs, together with data showing the feeding value of these various preparations as far as they can be determined from chemical analyses. There has also been a great deal of discussion concerning the presence of any poisonous qualities that might be possessed by the flax plant or the by-products from the same. There has been much difference of opinion as to whether the poisonous quality is due to the flax product itself or to some of the other ingredients, weed seeds, etc., that might be admixed with it. Professor Ince has carried out a very careful investigation to determine to what extent prussic acid might be present in the various portions of the flax plant at the different periods of growth. He has completed an important investigation confirming the findings previously published with regard to the poisonous qualities that may be the result of feeding flax roughage wherein considerable quantities of prussic acid may be present, and has pointed out the dangers that come from carelessness in methods of feeding these by-products.

The next study is of the influence of bran extract on the baking qualities of flour. The influence of the bran extract, prepared in various ways, upon the volume and character of the loaf of bread is presented as the result of careful studies which have been carried on and are still being made under the direction of Professor White. He also presents an article on the Phosphorous Content of Wheat and Wheat Flour and Its Relation to the Baking Qualities of the Flour. Here studies were made with regard to the total phosphorus, the organic phosphorus, the inorganic phosphorus, and the water-soluble phosphorus in flour from two varieties of North Dakota wheat. While this is but the first preliminary report, it shows much interesting and valuable data of what has been a perplexing question with regard to the relation of the loaf volume to the gluten and the ash or mineral constituents of the wheat flour.

It is hoped that the studies now in progress may be continued as we have here one of the most important fields of research work which should prove of immense practical value not only to the farmer but to the miller as well as to the baker.

E. F. LADD.

THE FERTILITY CONSTITUENTS IN FLAX.

By J. W. Ince.

"Flax has had a bad reputation, agriculturally, having long been regarded as a robber and poisoner of all soils with which it came in contact. But the investigations of some of our experiment stations have proved the falsity of these old errors of belief. . . . It has been demonstrated that an average crop of flax uses less total plant food per acre than a crop of potatoes, corn, wheat, or oats."

The above statement appears in Van Slyke's "Fertilizers and Crops," one of the latest and most authoritative books upon this important subject. In support of this assertion there is usually given in the bulletins of the experiment stations cited (North Dakota and Minnesota) the following table comparing acre yields and fertility out go.

TABLE I.
ACRE YIELDS AND FERTILITY LOSS.

	GRAIN				STRAW				TOTAL		
	Yield Bu.	Nitrogen lbs.	Phosphoric Acid lbs.	Potash lbs.	Yield T.	Nitrogen lbs.	Phosphoric Acid lbs.	Potash lbs.	Nitrogen lbs.	Phosphoric Acid lbs.	Potash lbs.
Corn	65	40	18	15	2	46	4	60	86	22	75
Wheat	20	25	12.5	7	1	10	7.5	28	35	20	35
Oats	50	35	12	10	1½	15	6	35	50	18	45
Flax	15	38	15	8	1	17	3.3	21	55	18.3	29

From a study of this table the origin of such statements as the following can readily be seen. "Flax is not hard on land. It is an error to suppose that the flax crop is especially hard on land. That idea arises wholly because certain root-rot or blight diseases cause the crop to die out on those lands which have once been infected by poor disease bearing seeds. The flax crop does not use up as much moisture or of soil fertility as either wheat or oats."

It is not the purpose of this article to question the existence or effect of flax-sick soils but rather to compare the manurial constituents of flax products from a different standpoint than acre yields. Tho the latter method of comparison has been the usual one, it is perfectly obvious that it is rather arbitrary to discuss the relative fertility in twenty (20) bushels of this substance with that in sixty-five (65) or one hundred and fifty (150) bushels of another substance.

There is shown in the following tables a comparison of the manurial constituents in equal quantities (100 pounds) of six grain crops, five oil bearing seeds, and six leguminous plants, and the average of all of these compared to flax alone. The figures were obtained from Van Slyke's "Fertilizers and Crops" and the money value computed from Hopkins basis of fifteen cents a pound for nitrogen, twelve cents for phosphorus and six cents for potassium.

It is seen from a study of these figures that, taking equal weights into consideration, flax seed contains over twice as much fertility as does the average of the six common grain crops cited; that flax-seed contains more manurial value than the highly nitrogenous oil bearing seeds; that with the exception of potassium, flax seed contains more fertilizing ingredients than do the seeds of the six legumes mentioned. Again, though flax straw contains less phosphorus and potassium than does the straw of legumes and grains, yet it occupies a position about half way between the latter two with regard to its nitrogen content.

These facts show that flax products are very rich in manurial constituents and that they ought to be very carefully conserved on the farm. Having due regard to the possibility of stock poisoning from eating green flax straw, chaff, etc., and also for the possibility of introducing flax diseases into soils, the farmer ought to save every pound of flax by-products and incorporate them into the soil somehow, either after feeding, or composting, or discing directly into the land.

TABLE II.
MANURIAL CONSTITUENTS IN 100 POUNDS.

	GRAIN OR SEED					STRAW OR STALKS				
GRAINS	Nitrogen (lbs.)	Phosphorus (lbs.)	Potassium (lbs.)	Total (lbs.)	Value (cents)	Nitrogen (lbs.)	Phosphorus (lbs.)	Potassium (lbs.)	Total (lbs).	Value (cents.)
Wheat	2.00	0.37	0.42	2.79	37.0	0.50	0.07	0.50	1.07	11.3
Oats	2.00	0.35	0.50	2.85	37.0	0.60	0.09	1.05	1.74	16.2
Barley	1.75	0.33	0.42	2.50	33.0	0.60	0.09	0.91	1.60	15.6
Rye	1.70	0.37	0.50	2.57	34.0	0.50	0.13	0.70	1.33	12.2
Millet	2.00	0.42	0.33	2.75	37.0	0.70	0.09	1.40	2.19	19.9
Corn	1.65	0.30	0.33	2.28	31.0	0.75	0.18	0.75	1.68	18.6
Average ..	1.85	0.356	0.416	2.62	34.4	0.61	0.11	0.885	1.60	15.6
Oil Bearing Seeds.										
Flax	4.35	0.66	0.80	5.81	78.0	0.85	0.09	0.83	1.77	19.0
Cottonseed	3.15	0.55	0.95	4.65	59.2	x	x	x	x	x
Sunflower	2.25	0.55	0.62	3.42	43.3	x	x	x	x	x
Hemp	2.50	0.77	0.83	4.10	50.5	x	x	x	x	x
Peanuts .... (Kernels)	3.60	0.31	0.37	4.28	60.0	x	x	x	x	x
Average....	3.17	0.57	0.71	4.45	58.6	x	x	x	x	x
Legumes										
Clover, red	3.00	0.66	1.15	4.81	60.0	2.10	0.22	1.65	3.97	*43.9
Beans, field	4.00	0.53	1.10	5.63	72.0	1.30	0.11	1.60	3.01	30.4
Peas, field	3.75	0.35	0.83	4.93	65.0	1.40	0.15	0.83	2.38	28.0
Beans, Soya	5.30	0.80	1.65	7.75	99.1	0.90	0.13	0.62	1.65	18.7
Cowpeas ..	3.10	0.44	1.00	4.54	57.8	2.50	0.25	1.45	4.20	*49.5
Vetch	3.70	0.60	0.71	5.21	66.9	1.00	0.11	0.54	1.65	19.3
Average ..	3.81	0.56	1.07	5.44	70.0	1.53	0.16	1.11	2.80	31.5
Omitting hay from average						1.15	0.125	0.90	2.17	23.9
Summary.										
Average of										
6 Legumes	3.81	0.56	1.07	5.44	70.0	z1.15	0.125	z0.90	z2.17	z23.9
6 Grains ..	1.85	0.356	0.416	2.62	34.4	0.61	0.11	0.88	1.60	15.6
5 oil bear'g	3.17	0.57	0.71	4.45	58.6	x	x	x	x	x
Flax	4.35	0.66	0.80	5.81	78.0	0.85	0.09	0.83	1.77	19.0

NOTES—x=not stated; *=hay; z=omitting hay from average.

It is interesting to note in this connection that the fertility in linseed meal is worth $19.06 per ton compared to $15.59 for that in flax-seed. The fertility in flax straw is worth $3.77 per ton. It pays to buy linseed meal for feed. It does not pay to burn flax straw stacks.

It is also of interest to compare the price received by the farmer for some of the principal grain crops with the fertility value contained in those same crops. This was done by securing from the Yearbooks of the U. S. Department of Agriculture the average farm price on December 1st. for the years 1900-1909 per bushel and computing this to a basis of price received per 100 pounds. The manurial value of these 100 pound quantities was secured from Table II. By changing these figures to the basis of the same amount of money received, it is possible to find the value of the fertilizing ingredients sold in one dollar's worth of a certain commodity. (See Table III)

TABLE III.

	Average Farm Price on Dec. 1 (1900—1909) for U. S.		Value of fertility in 100 lbs.	For every $1. received there is an outgo of fertility worth
	Per bu. (lbs.)	Per 100 lbs		
Corn	47.6c (56)	85.0c	30.0c	35.3c
Wheat	77.0 (60)	128.2	37.0	28.8
Oats	35.5 (32)	111.0	37.0	33.3
Barley	47.9 (48)	100.0	33.5	33.5
Rye	62.2 (56)	111.1	32.0	28.8
Flax (1902—1909)	104.8 (56)	187.0	78.0	41.7
Potatoes	57.4 (60)	95.6	8.6	8.9

It is apparent that for every dollar the farmer receives for wheat and rye there is an outgo of 28.8 cents worth of fertility; in the case of oats, barley and corn, a loss of fertility of 33.3-35.3 cents, while in flax there is a loss of 41.7 cents. Potatoes cause the smallest direct loss of any material in this table.

SUMMARY.

1. Flax contains, pound for pound, far more fertility than the ordinary grain crops.
2. All flax products should be carefully saved on the farm, and returned to the soil so as to derive all possible benefit from the fertility contained in them.
3. The farmer receives less return for the fertility in flax than for that in wheat, corn, oats, barley, and rye.

AN INVESTIGATION OF THE FEEDING VALUE OF FLAX MATERIAL AS DETERMINED BY CHEMICAL ANALYSIS.

By J. W. Ince.

In conjunction with the investigation of the presence of prussic acid in flax, it was thought advisable to utilize the material on hand for a series of determinations of the constituents of value in stock foods. In addition to the material used in the previous investigation, which came from several parts of North Dakota and which was gathered under various conditions, several samples of green flax straw were secured from Professor Bolley. These samples in every case had ripened seed present, so that they were mature but had been pulled to prevent weathering, etc. They were carefully threshed by hand and the seeds and bolls removed so as to give material corresponding with the other flax straws with the exception of color, weathering, etc. A more complete description of these specimens follows:

NOTE:—Excluding sample 83, which was of different character, all of the above samples had matured the flax seed belonging to them. The seed and bolls were, however, threshed out by hand and separated from straw and leaves. The samples, therefore, are free from grain and chaff and have been protected from the weathering action of sun and rain.

Table II. gives a description of the samples of mature flax straw, Table III. the screenings, and Table IV, the chaff samples included in this series of analyses.

The determinations of moisture, ash, ether extract, crude protein, and nitrogen in all the samples are grouped by classes to correspond with the descriptions given.—Tables V, VI, VII, VIII. Table IX is a summary of all the materials and shows at a glance the average composition of the samples analyzed. Table X contains a list of other analyses of flax substances made at various times in the past in this station and other stations. It is included in this report to show how extensive the use of flax material as a constituent of feeding stuffs has been and also to secure average analyses for the different kinds of flax by-products. The writer was unable to find this data in Henry's "Feeds and Feeding," and spent some time in collecting it from the various station bulletins and reports cited. However, the whole subject of the feeding value of flax is an important one in this state, and it is worth the effort to secure information to compare flax with other grain straws, chaff, screenings, etc. An examination of this table will show that flax plant material is a very common ingredient of molasses feeds and that it has been sold as "flax" material under the simple name of

TABLE III.—DESCRIPTION OF SCREENINGS.

Lab. No.	Where Grown	Color of sample	Further Information
38	Hettinger	Brown	Considerable flax seed, chaff, Russian thistle, and a large amount of dirt.
39	McLeod	Brown	Very little flax, mostly weed seeds and chaff, pigeon grass, lamb's quarters, pigweed, thistle.
40	Mott	Brown	Few weed seeds.
42	Fessenden	Brown	Few weed seeds.
45	Alsen	Brown	Broken flaxseed, grain chaff, pigeon grass, mustard, tumbling mustard, pigweed, lamb's quarters, hare's ear mustard.
82	Agricultural College	Brown	Chaff, flax and weed seeds.
36	Amenia		Very little flax seed, pigeon grass, lamb's quarters, pigweed.

TABLE IV.—DESCRIPTION OF CHAFF.

46	Alsen	Brown	Very few weed seeds.
61	Lakota	Brown	Very few weed seeds.

TABLE I.—DESCRIPTION OF GREEN FLAX SAMPLES.

Lab. No.	Where Grown	Date Collected	Stems	Leaves	Further Information
80	Agricultural College	9-19-1911	Upper Green	None	Dried outdoors.
79	"	10-30-1911	Green	None	Dried indoors.
83	"	9-19-1911	Green	None	2nd. growth
88	"	9-19-1911	Green	None	Dried indoors.
89	McHenry	9-10-1912	Green but slightly yellow	None	Dried indoors.
90	Dawson	Fall 1912	Green	Brown	Dried indoors.
91	McHenry	9-10-1912	Bright Green	None	Dried indoors.
92	Dawson	Fall 1912	Yellow Green	Brown & Yellow	Dried indoors.
93	Dawson	Fall 1912	Yellow Green	Green & Yellow	Dried indoors.
94	McHenry	Fall 1912	Yellow Green	None	Dried indoors.
95	McHenry	9-10-1912	Bright Green	None	Dried indoors.
96	Dawson	Fall 1912	Green	Plenty	Dried indoors.
97	Hensel	8-12-1912	Green	Brown	Dried indoors.
98	Hensel	8-12-1912	Yellow Green	Some	Dried indoors.
99	McHenry	9-10-1912	Green	None	Dried indoors.

TABLE II.—DESCRIPTION OF MATURE FLAX STRAWS (THRESHED).

Lab. No.	Where Grown	Color of sample	Further Information
29	Amenia	Brown	Chaff, some grain straw.
32	Oakes	Brown	
44	Fessenden	Brown	
47	Alsen	Brown	
48	Alsen	Brown & Green	
52	Englevale	Brown	
57	Pingree	Faded	Cut after frost, weathered.
65	Hettinger	Brown	Half thistle.
66	McLeod	Dark green	
71	Bowman	Brown	Standing, frosted.

screenings, bran, feed, etc., or under the rather fanciful names of "Ground flax flakes," "Laxo-cake-meal," "Flaxine," "Flaxo meal," etc. A discussion of the propriety of using some of these terms follows Table X.

TABLE V.—STOCK FOOD ANALYSES OF FLAX STRAWS—MATURE SAMPLES (GREEN AND UNWEATHERED).

Lab. No.	Where Grown	Percent Moisture	Percent Ash	Percent Ether Extract	Percent Crude Protein	Percent Nitrogen
67	Bowman	4.43	3.99	4.15	6.91	1.11
79	Agric. College	5.30	4.55	3.46	14.13	2.26
80	Agric. College	4.69	5.19	7.58	12.31	1.97
83	Agric. College	4.57	7.53	6.54	16.00	2.56
89	McHenry	5.86	5.49	4.05	4.17	0.67
90	Dawson	5.70	5.49	5.55	5.57	0.89
91	McHenry	5.53	3.93	4.75	5.22	0.83
92	Dawson	7.02	6.13	3.29	5.25	0.84
93	Dawson	5.55	8.09	4.29	10.12	1.63
94	McHenry	5.01	4.34	3.07	4.62	0.74
95	McHenry	4.58	5.10	2.41	6.02	0.96
96	Dawson	4.91	6.02	4.77	8.90	1.39
97	Hensel	5.77	6.79	3.83	9.39	1.50
98	Hensel	5.67	3.80	4.46	5.62	0.88
99	McHenry	5.41	4.96	2.77	5.14	0.83
88	Agric. College	4.48	4.01	1.86	6.87	1.10
Average of (16)		4.96	5.34	4.17	7.87	1.26

TABLE VI—STOCK FOOD ANALYSES OF FLAX STRAWS—MATURE SAMPLES (BROWN & WEATHERED).

29	Amenia	6.02	5.02	3.00	5.56	0.89
32	Oakes	5.62	4.81	2.51	9.12	1.46
44	Fessenden	5.06	3.66	3.37	10.32	1.65
47	Alsen	5.66	3.30	1.78	10.00	1.60
48	Alsen	4.30	4.70	3.96	11.44	1.83
52	Englevale	4.02	3.26	3.04	8.31	1.33
57	Pingree	3.57	2.58	9.22	10.15	1.62
65	Hettinger	4.27	6.87	5.52	14.07	2.25
66	McLeod	5.85	3.29	2.87	5.28	0.85
71	Bowman	3.34	3.17	5.12	7.94	1.27
Average of 10		4.47	4.06	4.03	9.22	1.47

TABLE VII.—STOCK FOOD ANALYSES OF FLAX SCREENINGS.

38	Hettinger	5.39	41.60	12.55	9.10	1.46
39	McLeod	4.57	7.30	8.60	16.75	2.68
40	Mott	4.88	10.35	10.62	19.44	3.11
42	Fessenden	4.94	4.21	9.35	14.31	2.29
45	Alsen	5.44	4.80	12.20	18.44	2.95
82	Agric. College	5.81	11.75	4.74	20.81	3.33
36	Amenia	6.15	4.68	8.36	18.87	3.02
Average of 6		5.29	7.18	8.79	18.10	2.89

NOTE: No. 38 is omitted from the average because of the presence of a large amount of dirt in the sample.

TABLE VIII.—STOCK FOOD ANALYSES OF FLAX CHAFF.

46	Alsen	5.13	5.44	3.74	8.37	1.34
61	Lakota	4.60	8.96	3.10	9.75	1.56
Average of (2)		4.86	7.20	3.42	9.06	1.48

TABLE IX.—AVERAGE OF DIFFERENT MATERIALS.

Materials	Percent Moisture	Percent Ash	Percent Ether Extract	Percent Crude Proteins	Percent Nitrogen	Samples
Flax straw, brown	4.47	4.06	4.03	9.22	1.47	10
Flax straw, green	4.96	5.34	4.17	7.87	1.26	16
Flax screenings	5.29	7.18	8.97	18.10	2.89	6
Flax chaff	4.86	7.20	3.42	9.06	1.48	2

SAME COMPUTED TO MOISTURE FREE BASIS.

Flax straw, brown		4.24	4.21	9.65	1.54	
Flax straw, green		5.62	4.38	8.28	1.32	
Flax screenings		7.57	9.45	19.09	3.03	
Flax chaff		7.67	3.59	9.50	1.55	

TABLE X.—A SUMMARY OF ANALYSES OF FLAX MATERIALS. (Secured from available Data.)

Name of material	Ingredients	Percent Moisture	Percent Ash	Percent Ether Extract	Percent Crude Protein	Percent N—free extract	Percent Crude fiber	Average No. samples	References
Flax feeds	See comments following table			13.45	15.07			22	See comments.
Linseed feeds	"			7.32	17.56		16.73	2	See comments.
Ground flax flakes	Flax seed screenings			12.42	16.40		10.25	3	See comments.
Flax meals	"			12.90	15.30		12.0	3	See comments.
"Laxo-cake-meal"	See comments following table			8.51	27.02			14	See comments.
Flax screenings	See comments			9.86	15.95		14.46	21	See comments.
Flax bran	See comments	5.96	6.01	3.57	9.08	34.51	39.78	4	See comments.
Flax chaff	See comments	6.77	6.48	4.17	9.60	45.02	29.32	5	See comments.
Flax plant by-product	See comments	8.46	7.78	3.45	7.42	33.87	39.25	2	See comments.
Flax straw, brown	See present report	4.82	4.05	3.90	9.17			11	See comments.
Flax straw, green	"	4.98	5.28	4.08	7.48			17	See comments.
Molasses feeds (with flax)	See comments	9.64		4.15	15.65			11	See comments.
Flax bran	Stems, pods, meal	7.0	5.0	2.9	17.3	33.1	34.7		Ind. Bulletin 141, 1910.
(Meal 23%		7.2	6.3	5.0	29.4	37.1	15.0		Ind. Bulletin 141, 1910.
(Bran 32%		7.8	4.4	3.5	19.1	34.3	30.9		Ind. Bulletin 141, 1910.
(Stems 45%		6.6	2.8	1.6	4.7	28.4	55.9		Ind. Bulletin 141, 1910.
Flax bran	Stems, pods.	7.4	5.7	4.3	6.0	34.9	41.8		Ind. Bulletin 141, 1910.
(Pods 59.95%		7.5	6.7	5.8	7.2	37.3	35.5		Ind. Bulletin 141, 1910.
(Stems 40.05%		7.2	3.4	2.5	3.5	28.5	54.9		Ind. Bulletin 141, 1910.
Flax screenings	Broken flax seed hulls 17%; flax stems 34%; Weed seeds 49%.	9.9	7.6	12.3	15.3	39.0	15.5		Ind. Bulletin 141, 1910.
Flax plant by-product	Flax stems 75%; flax pods 15%; flax seed 10%.	9.81	7.22	3.93	8.29	35.61	35.63		Flour & Feed, Aug. 1912
Green flax straw shives	See comments	4.69	4.17	1.93	8.00	29.36	51.85		Canada Experimental Farms 1912
Dew rotted flax straw shives	See comments	4.30	2.59	1.29	3.44	29.08	59.30		Canada Experimental Farms 1912

EXPLANATIONS AND COMMENTS OF FEED OFFICIALS.

Flax Feeds.

Vermont Bulletin 144—"This material has been found on sale on the Vermont markets for two years. Two or three different brands have been found. Originally the material appeared to be composed mainly of broken flax seed, straw and many seeds, or screenings (fox tail, pigweed, peas, lady's thumb, amaranth, kale, and other weeds, not to speak of some timothy and small grasses.) The only brand found upon sale March 1909 has been altered in its physical character in that it has been finely ground. Casual inspection does not indicate the presence of unground weed seeds."

Mass. Bulletin, 132.—"Flax Feed, so-called, is in reality ground flax screenings. Its chemical composition and character are uncertain, depending upon the relative amounts of inferior flax seeds and weed seeds present. The weed seeds impart to the material a bitter taste. While it may be fed in limited amounts mixed with high grade feed stuffs, it cannot be placed in the same class. The commercial value is also decidedly less."

Kentucky Bulletin, 156—"Flax Feed is a misnomer unless applied to whole ground flax seed." z

Conn. Agr. Ex. Sta. Report on Commercial Feeding Stuffs, 1908.—"One Flax Feed has been examined for weed seeds and the number of weed seeds varied from 21, 267 to 86,000 per pound and consisted principally of the varieties that are characteristic of grain screenings, such as pig-weeds, knot-weeds, charlock and black mustard, bottle grasses and other varieties. With these facts before us it is readily seen that the purchaser can depend upon a good crop of weeds after using the manure on his farm."

Vermont Bulletin, 138.—"One sample called "Ground Flax Flakes" was found to contain over 20% of apparently unground weed seeds."

Mass. Bulletin, 120.—"Flax Feed consists substantially of one-third small flax together with two-thirds weed seeds and other foreign material which are separated from the better grade of flax seed during the process of preparing the latter for the oil mills. This residue is ground and offered either as H. J. Flax Feed or Ground Flax Flakes. These feeds have a decidedly bitter taste and a noticeable odor of linseed oil.

In a feeding trial of the H. J. Flax Feed at the experiment station, the animals ate the feed rather grudgingly, when fed by itself but consumed it readily when mixed with other grain. The bitter taste of the feed was not imparted to the milk. Material of this character may vary considerably in composition depending upon the purity of the seed from which it is separated. One sample of Flax Flakes contained very little flax seed and consisted largely of weed seeds, oat and wheat screenings. This fact was proved both by a microscopic examination and by its comparatively low fat content."

LINSEED FEEDS.

Canada Experiment Farms, 1909:

"This was composed chiefly of the ground cleanings of the flax shipments. Its constitution will necessarily alter somewhat the condition of the flax seed as received at the mills,—the cleaner the seed the better the quality of the feed. For furnishing the nitrogenous part of the ration it would, we think, be decidedly inferior to bran, the protein being some three per cent less and in all probability not so digestible. The percentage of fat or oil is comparatively high, evidently due to the flax seed present. This large proportion of fat is, undoubtedly the chief feature in favor of this material. The fiber is decidedly high (from fragments of hay, straw, etc. present), and this fact detracts from the value of the feed as a concentrate."

FLAX SCREENINGS.

N. Y. Bulletin, 351.—"Screenings are the smaller imperfect grains, weed seeds and other foreign materials separated in cleaning the grain."

Mass. Bulletin, 132,—"Flax screenings are similar to wheat screenings excepting that the inferior wheat kernels are replaced by imperfectly developed flax seed. They likewise contain more protein and fat than the screenings from wheat, and have a somewhat greater nutritive value."

Canadian Experimental Farms, 1908.—Ground feed from flax screenings. This material was sent in from the Canadian Pacific elevator, Port Arthur, and is stated to be prepared almost entirely from the screenings from flax. Though the fibre content is somewhat high, the notable percentages of protein and fat give this feed a rank among the better class of feeding stuffs.

Flax Refuse or Screenings:—This, as received, represented the screenings from flax seed. It contained a considerable amount of flax bolls or seed-capsules, dried leaves and dead or immature flax seeds."

Ind. Bulletin, 161, "Laxo-Cake-Meal,"—Ground cake from flax seed, wheat, wild buckwheat, pigeon grass, wild mustard, inferior flax seed, flax pods and screenings."

FLAX BRAN.

Kentucky Bulletin 156.—"Flax Bran is a misnomer."

Ind. Bulletin 141,—"Flax Bran, as used by the manufacturers of compound feeds, is of variable composition and ingredients, but usually consists of flax pods, flax stems from which the tow has been extracted, and small flax seeds. The pods and stems are invariably present in largest amount. The sample containing no flax seed is low in feeding ingredients and high in crude fiber. While the one containing flax seed is relatively high in crude protein it also contains a high percentage of crude fiber. Since no method is available whereby the consumer can ascertain whether the material used under this name consists of pods, seeds, and stems, or merely stems, it is believed that no higher feeding value in general should be assigned it than to any other filler and that its use should be regarded as that of a filler to furnish bulk and roughness.

This product is sometimes used as an adulterant for alfalfa.

Careful investigation leads us to believe that the application of the term "Flax Bran" to mixtures of flax stems and pods or flax stems, pods and seeds, tends to mislead the consumer and that its use should be restricted to materials composed of the bran layer of the flax seed.

In accordance with the preceding, future registrations of mixtures of flax plant by-products will not be accepted under the name of flax bran, but must be registered under the name of Flax Plant Offal or Refuse, followed by a statement of the separate by-products composing same."

FLAX PLANT BY-PRODUCT.

N. Y. Bulletin 351.—"Flax Plant By-Product is the portion of the flax plant remaining after the separation of the seed, the bast fiber and portions of the shives; and consists of flax shives, flax pods, broken and immature flax seeds, and the cortical tissue of the stem."

Flour and Feed, August 1912, pg. 20.—"Flax Plant By-Product.—This material was treated as a waste product until recently but the high price of feeds has caused it to be utilized in mixed feeds. It acts as an absorbent or dryer for molasses. This feed consists chiefly of flax stems, pods, and broken pieces of flax seeds, about as follows:—Flax stems, 75%; flax pods, 15%; flax seed, 10%." This feed is very dusty and disagreeable to handle.

Flax Plant By-Product and Molasses.—This feed is the same as the preceding, mixed with just enough molasses so that it does not cake and is easy to handle."

Kentucky Bulletin 156.—"Flax Plant Refuse—is the flax shives, flax pods, inferior flax seeds, and the woody portion of the flax plant or any of the above materials."

Canadian Exp. Farms, 1912.—"Flax Straw Shives—The green flax straw shives and the dew-rotted flax straw, are in our opinion, quite unsuitable and worthless as feeds, not merely from their low content in protein and fat and their excessive percentages in fiber, as shown by analysis, but by reason of their very coarse and extremely harsh nature. It is of interest to note that on all counts the dew-rotted is much the inferior."

FLAX CHAFF.

Canada Exp. Farms, 1912.—" The flax seed chaff consisted essentially of chaff, but there was also present a considerable amount of flax straw which is of a particularly harsh and brittle nature. The analysis shows a notable amount of protein, evidently from the presence of a certain quantity of flax seed. It might, therefore, in spite of its high fiber-content, be supposed to be of some feeding value. If by fanning or sieving the proportion of chaff and fragments of straw could be reduced, it would rank with the many feeds of recognized worth, but in its present condition, its value as a feeding material is extremely doubtful. We think that it would be found unpalatable and possibly injurious by reason of the brittle, harsh straw it contains."

Canada Exp. Farms, 1906.—"Flax Chaff—obtained in the cleaning of flax, being light and separated by wind, consists chiefly of the broken seed pods of the flax. A very poor feed as regards protein, and though the flax seeds that are present furnish a fair percentage of fat, the material must be considered as distinctly low-grade."

MOLASSES FEEDS.

A large number consists of cereals, by-products, flax shives, flax seeds, oat clippings, flax pods, screenings, flax stalks, grain screenings, oat hulls, salt, and molasses.

Names of some commercial stock feeds containing flax material as a constituent. (This list does not include feeds containing flax seed or linseed meal.)

Ind. Bul. 161; International Sugar Feed Co., Minneapolis, Minn.:—International Hog Feed and Charcoal, International Horse Feed, International Special Molasses Feed, International Cattle Feed, International Molasses Feed, International Dairy Feed.

North-West Mills Co., Winona, Minn.:—Sugarota Dairy Feed, Sugarota Horse Feed, Sugarota Cattle Feed, Sugarota Swine Feed.

The Quaker Oats Co., Chicago, Ill.:—Quaker Dairy Molasses Feed, Daisy Dairy Feed.

Champion Feed Milling Co., Lyons Iowa:—Champion Digester Hog Feed, Champion Molasses Feed.

F. S. Burch & Co. Inc., Chicago, Ill.—Petaluma Egg Producer.

The Capitol Food Co., Piffin, Ohio.—Capitol Stock Remedy, Capitol Poultry Remedy, Capitol Animal Regulator.

Wilbur Stock Food Co., Milwaukee, Wis.—Wilbur's Stock Food, Wilbur's Poultry Food.

International Stock Food Co., Minneapolis, Minn.:—Gro-fast Calf Meal.

Allneeda Mills Co., East St. Louis, Ill.—Allneeda Cow Feed.

Prussian Remedy Co., St. Paul, Minn.—Prussian Stock Tonic.

La Clede Mills, St. Louis, Mo.—Alta Dairy Feed.

THE FEEDING VALUE OF FLAX STRAW AND FLAX PLANT BY-PRODUCTS.

Practical experience and chemical analyses have certainly demonstrated the utility of flax products (straw, chaff, etc.) as stock foods. As has been shown, extensive use of these by-products is made in large grain centers as ingredients of molasses feeds and certain flax feeds and even as a filler in condimental stock tonics and feeds. A good many farmers of North Dakota have stated that they have fed flax straw with excellent results to cattle, sheep, and horses; that the animals seem to relish the material, leaving other kinds of roughage to eat the flax; that milch cows increase their flow of milk when turned into the flax stack; and that they seem to be able to maintain themselves thru the winter upon flax as a major portion of their feed. Some experiment station experts also state that they have fed flax straw thru a winter (owing to a scarcity of other fodder) with fair results; that they consider flax straw as satisfactory and safe for cattle as other grain straws, and that they do not believe flax straw will cause intestinal estoppage any more than any other straw if it is fed with moderation and with care to keep the bowels in good condition.

On the other hand, there are several objections to the use of such flax substances as feeding stuffs. The possibility of the presence of a deadly poison, prussic acid, has already been noted in other reports (N. Dak. Sp. Food Bull. Vol. I, Nos. 31 and 35,—Experiment Sta. Annual Report 1911, pt. 2.). The presence of nearly half its weight of crude fiber in the straw is surely a serious objection to the use of this material since it lessens the quantity of available food material and throws a heavier burden upon the animal in digesting his food; and the peculiar properties of the flax fiber, its great strength and characteristic "Balling" when ground, indicate what must happen in the digestive organs of the animal. Anyone who has ever attempted to grind flax straw will appreciate the tenacity of the fiber and wonder that animals can desire or digest the same without a great demand upon their energy. One experiment station expert has stated that in his opinion it would be just as sensible for human beings to attempt to eat the boughs of trees as for animals to eat flax straw.

With one exception (to be noted later) there do not seem to be any very definite facts about the value of flax straw and flax plant by-products as feeding stuffs. It is mostly a matter of general observation of a personal nature, such as some of those opinions already cited. The following paragraph appears in Henry's "Feeds and Feeding."

"Where flax is grown for seed, the straw or haulm is generally wasted. Stockmen who have fed flax straw to horses and cattle report satisfactory results from its use. Frequently some flax seed is left in the straw, which increases its value. There seems no foundation for the statement that the fiber of flax straw forms balls of indigestible material in the stomachs of farm animals. It is no doubt digested the same as other fibrous matter—the lint of cotton for example. Some flax straw may always be fed, and during times of scarcity it will prove a boon to the stockman who overcomes his prejudice and supplies it freely to his hungry animals."

The following are some opinions of farmers as expressed in the Dakota Farmer within the last two years.

D. S. Jamestown, N. Dak.

"In considering flax straw we notice that cattle prefer the chaff at the back and bottom of the stack above anything that they can pick up at that time of the year. The straw, however, being very stalky and fibrous is difficult to chew and on this account the cattle seem to prefer other kinds of straw. Horses, however, chew it easily and prefer it to any except oat straw. In fact I have fed flax straw to horses, in the barn, that were not working, to take the place of hay. Getting a small amount of feed with the roughage, the horses kept up in good shape. I have known sheep to have been fed on flax chaff every day, as roughage, with hay at night."

J. S. G. Logan Co. N. D.

"Feeding Flax Straw.—Some horses are dying from eating it, but it is because they are hungry and eat too much at a time. I haven't had any trouble yet. I turn my mares out and also the cows, but do not let them eat over a couple of hours at first for a day or so. Give them plenty of salt and water and if there is not much threshed flax in the straw it won't hurt them. Turn them loose to straw, hay range and stubble and they won't eat enough flax straw to injure them."

G. J. S. Edmunds Co., S. D.

"For the last five years I have fed flax straw in quantities of full loads and gave all stock full sway to it, with one ration of good hay at night. I have also let all my stock run to flax stacks in the fields, with one ration of hay daily. I have not had one single case of abortion in either mares, cows or ewes. Where there is not too much flax seed left in the straw, I believe there is absolutely no danger in its use, but if the straw is full of seed I would not advise anyone to feed it. I always winter from thirty to sixty head of stock."

P. O. Pierce Co., N. Dak.

"In the year of 1902 I had 400 acres of flax. All of it froze in the fall. It was cut with the binders with flax attachment and was stacked with bull rakes and hay stacker. That year was a wet one and there was straw to make 20 or more bushels per acre. After it was stacked we started to thresh it and it did not take long to see that the flax seed threshed would barely pay for the threshing, so we quit. I had previously been corresponding with Prof. Thos. Shaw, asking his advice and the feeding value of flax not threshed. and Prof. Shaw said by all means save it for feed but not to feed it altogether. That following winter I had nearly 200 head of cattle. Horses and cattle alike were fed the whole flax crop and they relished it, and did fine. They were fed a small load of flax to a load of hay, but they would leave the hay to get the flax. The leaves and even the blossoms kept bright in the stacks all winter."

H. L. B. Fargo, N. Dak.

"In the northwest the flax straw is commonly used as roughage for cattle during the winter. Many farmers report great success in using it in combination with other straws and hay. Some few cases of stock poisoning have been attributed to feeding upon flax screenings and chaff. As such crops, however, are often grown upon new lands it is very possible that this poisoning is due to the presence of some of the seeds or parts of poisonous plants such as hemlock or pine cockle."

The only experiment (which the writer could find described) carried on to determine the coefficient of digestion of any kind of flax material, except seed and oil meal, was executed in the Maryland Expt. Station by Dr. Patterson and H. J. White. An official account of this experiment is given in Bulletin 168 of the Md. Station, and "Flour and Feed" in the August, 1912 number, from which the following account is reported:

DURATION OF EXPERIMENTS.

"Each test was divided into two periods; first, a preliminary period which was for the purpose of getting the animal accustomed to each feed and also to give time for the feeds used previously to be entirely out of the system.

STEERS USED.

Two grade short-horn steers were used for making the digestibility test. They were quiet and easily handled. They were in fair flesh and were fair feeders.

The weights during each period are given in Table XI. The weights fluctuated somewhat, but rather less than usual in such work.

TABLE XI.—SHOWING WEIGHTS OF STEERS DURING EXPERIMENTS.

Period	Steer No.	Weight at beginning of preliminary.	Weight at beginning of digestion	Weight at end of digestion
I	1	850	905	866
	2	940	903	877
II	1	866	868	876
	2	877	855	901

Ration for period No. I, was Flax By-Product.
Ration for period No. II, was Flax By-Product and Molasses.

TABLE XII.—SHOWING THE DIGESTIBILITY OF FLAX BY-PRODUCT PERIOD I; LENGTH OF PRELIMINARY PERIOD SEVEN DAYS; AND DIGESTION PERIOD FIVE DAYS.

Weight in Grams (453.6 Grams—1 pound.)

		Dry Matter	Protein	Fiber	Ether Extract	Corbohydrates
Amount eaten by 2 steers	(1)	13091.1	1203.3	5170.8	570.6	5173.9
	(2)	29474.4	2709.5	11644.1	1284.6	11641.1
Amount digested by 2 steers	(1)	5495.8	674.6	1709.3	361.7	1394.6
	(2)	17379.3	1939.0	7407.7	909.3	6861.9
Digestion coefficient (See note *).		50.52%	63.43%	48.32%	74.95%	42.97%

* Average percentage digested by 2 steers.

TABLE XIII.—SHOWING THE DIGESTIBILITY OF FLAX BY-PRODUCT AND MOLASSES; DIGESTION PERIOD II; PRELIMINARY PERIOD NINE DAYS; AND DIGESTION PERIOD FIVE DAYS.

Weight in Grams (453.6 Grams—1 pound.)

		Dry Matter	Protein	Fiber	Ether Extract	Carbohydrates.
Amount eaten by 2 steers	(1)	38194.0	5158.7	9822.4	1323.0	18326.3
	(2)	34449.0	4642.9	8859.6	1139.2	16515.6
Amount digested by 2 steers	(1)	20274.5	3344.9	2573.6	831.4	11117.4
	(2)	19534.8	2822.9	3317.8	644.8	10669.5
Digestion coefficient (See note *.)		54.89%	62.50%	31.84%	59.72%	62.63%

It is readily seen from a study of the figures given above and a comparison of them with those given in the Table XIV below, that the flax plant by-product furnished on the average about the same amount of digestible nutrients as timothy hay, nearly twice as much digestible fat and protein as is furnished by timothy hay, more digestible nutrients than corn-fodder, but not quite as much as clover hay. The molasses seemed to increase the digestibility of the total dry matter, and the carbohydrates, but caused a decrease in the digestibility of the protein, fat and fiber."

TABLE XIV.—AVERAGE COMPOSITION, DIGESTIBLE NUTRIENTS, AND DIGESTION COEFFICIENTS OF FEED STUFFS ROUGHAGE.

ROUGHAGE	COMPOSITION						Digestible nutrients —in 100 pounds			Digestion coefficients			
	Water	Ash	Crude Protein	Crude Fat	Crude fiber	Nitrogen free extract	Crude Protein	Crude fat	Carbohydrates	Crude protein	Crude fat	Crude fiber	Nitrogen free extract
Corn fodder, field cured	42.2	2.7	4.5	1.6	14.3	34.7	2.5	1.2	34.6	55.0	74.0	65.0	73.0
Corn stover, field cured	40.5	3.4	3.8	1.1	19.7	31.5	1.7	.7	32.4	45.0	62.0	67.0	61.0
Corn silage	79.1	1.4	1.7	.8	6.0	11.0	.9	.6	11.5	49.3	80.0	66.7	68.6
Barley straw	14.2	5.7	3.5	1.5	36.0	39.0	.7	.6	41.2	20.0	42.0	56.0	54.0
Wheat straw	9.6	4.2	3.4	1.3	38.1	43.4	.4	.4	36.3	11.0	31.0	52.0	38.0
Oat straw	9.2	5.1	4.0	2.3	37.0	42.4	1.2	.8	38.6	30.0	33.0	54.0	44.0
Rye straw	7.1	3.2	3.0	1.2	38.9	46.6	.6	.4	40.6	21.0	32.0	60.0	37.0
Alfalfa hay	8.4	7.4	14.3	2.2	25.0	42.7	10.6	.9	38.9	74.0	39.0	43.0	66.0
Timothy hay	13.2	4.4	5.9	2.5	29.0	45.0	2.8	1.4	43.4	48.0	57.0	52.0	63.0
Red clover hay	15.3	6.2	12.3	3.3	24.8	38.1	6.8	1.7	35.8	55.0	53.0	46.0	64.0
White clover hay	9.7	8.3	15.7	2.9	24.1	39.3	11.5	1.5	42.2	73.0	51.0	61.0	70.0
Alsike clover hay	9.7	8.3	12.8	2.9	25.6	40.7	8.4	1.5	42.5	66.0	50.0	53.0	71.0
Wheat screenings	....	....	12.50	3.0	4.90	65.10	9.80	2.2	51.0	78.4	73.3	....	76.7
Flax plant by-product	9.81	7.22	8.29	3.93	35.63	35.61	5.3	2.94	15.30	63.4	74.9	48.3	42.9
Flax plant by-product & molasses	17.45	7.83	11.15	2.73	21.23	39.61	6.97	1.63	24.8	62.5	59.7	31.8	62.6

NOTE:—The data for this table were taken largely from "Jordan's Feeding of Farm Animals", "Voorhees' Forage Crops", "Henry's Feeds and Feeding", "Miss. Bull. 123," and "Flour and Feed."

SUMMARY.

1. The present report is a collection of data showing the feeding value of flax straw. and flax plant by-products. Moreover, the extensive use of these materials in commercial stock foods is indicated.

2. There are given results of analyses upon samples of flax screenings, chaff, and straws collected in North Dakota during the year 1912.

3. There are also given the average analyses of a large number of flax by-products collected from available data in Experiment Station reports.

4. The results of a feeding experiment and the opinions and experiences of several farmers as to the feeding value flax straw, etc. are included.

5. The composition and digestibility of flax plant by-product and other straws and hays are compared. This particular flax material ranks very high in digestibility, apparently containing seven times as much digestibie protein in 100 pounds of raw material as the more common grain straws, five times as much digestible crude fat, but less than half as much digestible carbohydrates.

6. The flax by-products that have been used in stock foods may be divided roughly into two classes,—high and low grade. As regards crude protein, the presence of broken flax-seed and weed seeds apparently produces high grade (with a range of from 15.0 to 17.5% protein,—in one case 27.0%) and practically all stems. pods, chaff, etc. give the low grade (with a range of from 7.5% to 9.5%)

7. As regards ether extract or crude fat, the highest grade material ranges from 7.5% to 13.5% and the lower grade from 3.5% to 4.2%.

8. Crude fiber is high in every case, tho the products containing flax-seed and weed-seeds are not unreasonably so.

9. It is thus seen that the composition of these different feeds depends a great deal upon the presence of flax seed and weed seeds; that samples containing such screenings are surprisingly high in protein and fat; and that flax bran, chaff, flax plant by-product and flax straw are very similar in composition.

10. Flax straw and other coarse by-products of the flax plant are shown to be much richer in protein than the other straws, occupying a position about half-way between the grain straws and the legume hays.

11. As far as crude fat is concerned, the flax by-products excel in amount all the other roughage products listed.

12. It is not surprising, then, that animals may eat the flax products in preference to other roughage and it would seem that the farmer is justified in feeding this material, provided, of course, he feeds it moderately and with due precautions against poisoning.

13. There would still seem to be, however, the desirability of more feeding experiments to learn the digestion coefficients of flax straw and other flax roughage.

ACKNOWLEDGMENTS.

The writer desires to acknowledge the assistance of the following in securing the data for this report:

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A FURTHER STUDY OF THE DISTRIBUTION OF PRUSSIC ACID IN THE FLAX PLANT.

By J. W. Ince.

Reports have already been published from this Station describing certain experiments and studies in regard to the occurrence of the poison, prussic acid, in different parts of the flax plant. The reasons for the investigation were described in Special Food Bulletins Nos. 31 and 35 of Volume I, and in the twenty-second Annual Report of the North Dakota Agricultural Experiment Station.

Because of the fact that flax straw is fed considerably in this state, it was thought advisable to continue the investigation another season and secure samples from different parts of the State and from as many conditions as possible. Accordingly letters were sent to a number of farmers and agricultural experts asking their co-operation. Moreover, a number of samples of flax were gathered from the Agricultural College farm at different times during the growing season. In this way about eighty (80) samples of various kinds were collected and analyzed.

A description of the samples collected from the state follows in Table I. As will be seen from a study of the data, the material came from sixteen places fairly well distributed over the state. The samples can be grouped under the heads of chaff, screenings, threshed straw, and the entire flax plant. The presence of bolls and of foreign material, as weed seeds, other straws, etc., is listed in order to answer any question that might arise concerning those substances. For example, it has been suggested that the poisoning of the cattle in cases already referred to might have been due to the presence of immature bolls. Also that the poisoning might have been due to the presence of poisonous weed seeds or parts of weed plants. From a study of the data given below, it can be seen that there is no connection between the presence of the bolls and the poison. The same fact holds with regard to the mutual presence of weed seeds and prussic acid.

TABLE I.—DESCRIPTION OF FLAX SAMPLES, SEASON 1912.

Lab. No.	Where Grown	Character of sample	Color	Bolls present	Weed seeds present	Percent Prussic Acid
31	Hastings	Entire plant	Brown	Yes	None	None
29	Amenia	Threshed straw and chaff, some grain straw	Brown	Very few	None	0.005
36	Amenia	Screenings, very little flax seed		None	Pigeon grass, Lamb's quarters, pigweed.	None
37	Amenia	Entire plant, some grain straw	Brown	Yes	Pigeon grass	0.005
32	Oakes	Threshed straw	Brown	Very few	None	None
35	Oakes	Standing flax, grain straw	Brown	Yes	None	0.001
33	McLeod	Standing flax	Green	Yes	None	None
39	McLeod	Screenings, very little flax, mostly weed seeds and chaff.	Brown	Yes	Pigeon grass, Lamb's quarters, pigweed, thistle.	None
66	McLeod	Threshed straw	Dark Green	None	Very few	None
38	Hettinger	Screenings, chaff, considerable flax seed great amount of dirt.	Brown	Yes	Thistle	None
69	Hettinger	Entire plant, about half thistle	Brown	Yes		None
65	Hettinger	Threshed, half thistle	Brown	Yes		None
72	Jamesto'n	Threshed	Brown	Few	None	None
73	Jamesto'n	Entire plant	Brown	Yes	None	None
40	Mott	Screenings	Brown	Yes	Few	None
41	Mott	Standing flax	Brown	Yes	None	None
42	Fessenden	Screenings	Brown	None	Few	None
43	Fessenden	Standing	Brown	Yes	None	0.001
44	Fessenden	Threshed	Brown	None	None	None
45	Alsen	Screenings	Brown	None	Nearly all weeds	None

TABLE I.—DESCRIPTION OF FLAX SAMPLES, SEASON 1912 —Continued.

Lab. No.	Grown	Character of sample	Color	Bolls present	Weed seeds present	Percent Prussic Acid
46	Alsen	Chaff	Brown	None	Very few	None
47	Alsen	Threshed	Brown	None	Very few	None
48	Alsen	Threshed	Brown & Green	None	Yes	None
49	Alsen	Standing	Brown	Yes	None	None
50	Alsen	Standing weathered	Grey	Yes	None	None
61	Lakota	Chaff	Brown	Few	Few	None
62	Lakota	Threshed	Brown	Yes	Few	None
63	Lakota	Cut flax	Brown	Yes	Few	None
64	Lakota	Fine straw	Brown	Few	Few	None
51	Lisbon	Threshed	Brown	Few	Few	None
52	Englevale	Threshed	Brown	Few	Few	None
53	Englevale	Threshed	Brown	Few	Few	None
54	Englevale	Threshed	Brown	Few	Few	None
55	Milton	Cut flax	Brown	Yes	Yes	0.008
56	Milton	Standing	Brown	Yes	Yes	None
57	Pingree	Cut after frost, weathered	Faded Brown	Yes	None	None
58	Pingree	Standing, frosted	Brown	Yes	None	None
59	Pingree	Flax seed	Brown			0.010
67	Bowman	Threshed	Green	Few	None	0.010
68	Bowman	Standing, frosted	Brown	Yes	None	0.004
69	Bowman	Standing, frosted	Brown	Yes	None	0.003
70	Bowman	Standing, frosted	Brown	Yes	None	None
71	Bowman	Standing, frosted	Brown	Yes	Thistle	0.002
72	Jamesto'n	Threshed, bleached	Brown	Few		None
73	Jamesto'n	Entire plant	Brown	Yes		None
74	Carrington	Threshed, some grain straw	Brown	Very few	Very few	None
75	Carrington	Entire plant	Brown	Yes	....	None
76	Carrington	Entire plant, wilt resistant	Brown	Yes	pigeon grass	0.008

A record of dates and rainfall conditions after cutting and threshing is given in Table II. This information was secured to answer the following questions: Does the time of planting have any effect upon the amount of poison in the mature flax? Does drouth cause abnormal changes in the plant and produce prussic acid in excess of normal conditions? Does rain, after cutting or threshing, bring about changes in the poison and wash it out of the flax plant? Out of all the samples listed in this table only seven were found to give a decided test for the poison. Comparing these with the other samples in the group, there does not seem to be any relation between the time of planting and the presence or absence of prussic acid. Drouth was reported where four samples gave the test, tho it was not reported where two samples gave the test. Rain was reported in six cases that gave the test for prussic acid, but also in 24 cases that failed to respond to the test, indicating the possibility of the poison being washed from the plant. Taking all the data in table II into consideration, however, there seems to be no very definite information as to the correlation of the different factors described, at least for the samples examined in this series. The information thus secured was disappointing in a way, for we had hoped to be able to establish some connection between the presence of the poison in the flax and the conditions surrounding the flax in question. It is possible, tho, that in certain seasons these factors might harmonize more.

A description of the flax samples collected at the Agri cultural College during the season of 1912 is given in Table III. A careful study of the data tabulated in I and III shows at once that there is a decided difference in the percentage of prussic acid in green and brown flax material. In fact the basis of color can be used as the simplest test for the possible presence of this constituent. While all flax substances undoubtedly contain some of this poison, the quantities present in ripened or mature or bleached straw, chaff, etc., are so small that they cannot cause poisoning of stock if eaten in moderate quantities. On the other hand the presence of prussic acid in young and other green flax samples is quite large and will undoubtedly cause death of cattle in the same way that second growth sorghum does.

As stated in other reports, the percentage of the poison seems to decrease as the flax nears the stage of maturity. Several of the analyses in this table indicate rather clearly the fact that different varieties of flax may contain different

TABLE II.—GIVING A RECORD OF DATES AND RAINFALL CONDITIONS AFTER CUTTING AND THRESHING.

Lab. No.	Date when seeded	Date when cut	Date when threshed	Was there rain after cutting	Was there rain after threshing	Did the flax suffer from drouth
72. 73	June 1st.	Sept. 10th.	October 20th.	Yes	No	No
31	May 25th.	....	....	Yes	....	....
29, 36, 37	May 23rd.	August 16th.	October 12th.	Yes	No	....
32, 35	May 31st.	....	Sept. 22nd.	Yes	....	
33, 39, 66	May 31st.	Sept. 14th.	October 4th.	Yes	Yes	No
38, 60, 65	June 5th.	October 15th.	Nov. 19th.	Yes	No	Yes, about July 20th.
45-50 incl.	June 6th.	October 10th.	October 23rd.	Yes	No	No
61-64 incl.	May 20th.	Sept. 25th.	Oct. 10th.	Yes	Yes	No
55, 56	June 25th.	....	....	....	....	About planting time
57-59	June 20th.	October 6th.	Nov. 10th.	Yes	....	No
52	....	Sept. 5th.	....	Yes	No	No
63	June 12th.	October 6th.				
67, 68					Often	In June
70, 71					Yes	In June

quantities of the poisonous principles; namely, a comparison of samples 1 and 4, of 34 and 14, of 22 and 21,—in each case the last number of which is golden flax shows that this particular variety has several times as much prussic acid as the more common variety. Similarly with numbers 13 and 20, in which the latter is white flax, the same relation holds true It is also noticeable that all the samples pulled on August 3rd, with the exception of 20 and 26, have about the same percentage of prussic acid.

After the analyses described in this report had been tabulated, the writer found a reference to some experiments carried on by J. V. Eyre (England) described in the Chemical News 106 (1912), No. 2758 which substantiates the above notes. Eyre says: "Those species of flax which resemble Linum usitatissimum or L. perenne in general habit of growth and which carry blue, white, or red flowers, are more or less richly cyanophoric (that is, contain the poisonous principle), whilst the yellow-flowered species, L. flavum, L. arboreum, L. maritimum, etc. which differ in habit from common flax, contain neither enzyme nor glucoside."

"The amount of cyanophoric glucoside present in different species is different, and is subject to variation throughout the period of growth. White flowering perennial flaxes invariably contain prussic acid long after its disappearance from the blue-flowered varieties of the same species."

"The development of glucoside and of active enzyme in the seed is found to be slow, and the process of ripening, although apparently without much influence on the enzymic activity, occasions a steady decrease in the amount of cyanophoric glucoside present in the seed. Ripe seed is found to contain no cyanophoric glucoside."

In order to readily compare the percentage of prussic acid in the different kinds of flax material examined in this series of analyses, the average percentage of the poison in all the samples is reported in Table IV. It is at once apparent that there is a marked difference in the amount of poison present in the samples of different character. As stated above, the question of the maturity of the flax seems to be the predominant factor in causing this difference. The difference in the character of the screenings is also very striking, there being apparently no relation between the groups of samples analyzed in 1911 and 1912. It is important to note that the percentage of prussic acid in the screenings that were sent in during the winter of 1910-1911 is nearly as great as that in the young flax samples gathered during the season of 1911.

TABLE III.—DESCRIPTION OF FLAX SAMPLES COLLECTED AT AGRICULTURAL COLLEGE DURING SEASON OF 1912.

Lab. No.	Date Collected	Character of sample	Color	Bolls present	Percent Prussic acid
25	July 3rd.	Principally flowering stage	Green	Few young	0.067
1	Jul. 15th.	Young, 2½-in in height	Green	None	0.032
3	Jul. 26th.	Young, 3 to 4 in. in height	Green	None	0.013
2	Jul. 24th.	Young, 5 to 7 in. in height	Green	None	0.026
4	Jul. 15th.	Golden flax, 1½—2-in.	Green	None	0.095
8	Aug. 2nd.	Just before blooming	Green	None	0.130
9	Aug. 3rd.	Some flowers, bolls partly formed	Green	Yes	0.049
11	Aug. 8th.	A few flower buds	Green	None	0.072
15	Aug. 15th.	Bolls forming and flowers	Green	Yes	0.069
10	Aug. 26th.	Some flowers; bolls in all stages	Green	Yes	0.056
16	Aug. 31st.	Few flowers; bolls in all stages	Green	Yes	0.008
17	Sept. 5th.	Bolls in all stages	Green	Yes	0.019
18	Sept. 12th.	A few mature bolls	Green	Yes	0.038
19	Sept. 19th.	Bolls in all stages	Green	Yes	0.026
28	Sept. 27th.	Frosted, all stages of growth	Green & Brown		0.040
27	Jul. 10th.	All stages, few flowers, some mature bolls, stalks green	Green & Brown		0.033
14	Oct. 3rd.	Golden flax	Green	Few	0.190
34	Oct. 3rd.	All stages, no flowers	Green & Brown	Yes	0.016
21	Oct. 29th.	Golden flax, some rye	Green	Yes	0.067
22	Oct. 29th.	About ½ sample mature	Brown	Yes	0.005
12	Aug. 3rd.	Select Russian, flowers, bolls in all stages	Green	Yes	0.033
13	Aug. 3rd.	Early Minn. 25, all stages	Green	Yes	0.032
20	Aug. 3rd.	White flax, all stages, flowers, bolls	Green	Yes	0.183
23	Aug. 3rd.	Argentine, flowers, bolls, all stages	Green	Yes	0.036
24	Aug. 3rd.	Russian, flowers, bolls, all stages.	Green & Brown	Yes	0.026
26	Aug. 3rd.	Argentine, dead	Brown	Yes	0.021
5	Oct. 4th.	Volunteer young flax	Green	None	0.043
6	Oct. 17th.	Volunteer young flax	Green	None	0.208
7	Nov. 1st.	Volunteer, after two hard frosts	Green	None	0.045
30		Volunteer, from another field	Green	None	0.058

TABLE IV.—SHOWING THE AVERAGE PER CENT OF PRUSSIC ACID IN FLAX SAMPLES, (ANALYSES REPORTED UPON AIR DRY PORTIONS.)

Kind of material		Number of samples	Percentage of Prussic Acid
Screenings, 1910—1911 (reported to have caused poisonings)		6	0.124
Young flax, season 1911		16	0.144
Young flax, season 1912		11	0.082
More mature flax, green	1911	20	0.043
More mature flax, green	1912	19	0.043
Ripe flax, entire plant	1912	20	0.001+
Threshed straw	1912	17	0.001—
Screenings	1912	6	0.000
Cnaff	1912	2	0.000

When the poisoning of stock in the winter of 1910-1911 first became known and the samples of flax screenings were sent in to the station for the determination, if possible, of the poisonous principle, it was at first thought that there might be present either the weeds of some poisonous plant or some parts of such plants. In order to answer this question, the very first work done upon the samples was to have them analyzed by Professor O. A. Stevens, who was unable to find either poisonous weed seeds or parts of poisonous plants. The ingredients of these samples of screenings, as far as they could be determined, are shown in Table V.

A description of the flax samples analyzed during 1911 is also included here for comparison with those of 1912. Most of the analyses were not reported in the previous accounts of the experiments. From a study of these figures it is seen that the effect of maturity upon the amount of poison present is the same as noted for the 1912 samples. The effect of weathering also seems to be to diminish the poison. It is also evident that most of the poison is in the leaves and upper stems. Flax by-product and flax bran, which are composed of mature stems, pods, etc., and which are used as fillers for stock foods, failed to give a test for prussic acid. The complete description of these samples is found in Table VI below.

TABLE V.—CONTENTS OF SAMPLES OF FLAX SCREENINGS REPORTED TO HAVE CAUSED THE DEATH OF ANIMALS, 1910—1911.

Locality	Seeds present (weeds)	Green Flax	Chaff and Straw	Tame seeds	Percent Prussic acid
1159 S	Mustard, pigeon grass wild oats, lamb's quarters, pigweed.	About ¼ leaves and immature seed bolls.	Considerable straw of other grains.	Flax, oats, wheat	x
1164 S	Cockle, sunflower, pepper grass, tumbling mustard, thistle.	About ½ flower buds and seed bolls, leaves.	Chaff and stems, weed stems	Flax, oats, wheat	0.057
1175 S	x	x	x	x	0.102
Jamestown		Some green bolls, large number of flower buds.	Large amount	Flax, oats.	0.178
Fordville	Wild oats, wild buckwheat, smartweed, pigeon grass.	Large amount green bolls and flower buds.	Considerable straw, some chaff	Flax, oats.	0.069
Anamoose	Mustard, wild oats, lamb's quarters, Russian thistle.	Large amount flower buds and bolls.	Considerable straw	Flax, wheat, millet	0.243
Carrington Original	x	x	x	x	0.097
3rd. Feeding		Considerable amount of Flower buds and bolls.	Large amount of straw and chaff	Very little flax seed.	.105

x Not determined.

TABLE VI.—DESCRIPTION OF FLAX SAMPLES ANALYZED.—1911.

Lab. No.	Date Collected	Source	Character of sample	Color	Bolls Present	Percent Prussic acid
1			Flax By-product (1234s) International Flax Twine Co., St. Paul, Minn.	Brown	No	.00
76			Oil Cake (1158s).	Grey Brown		.059
75			Flax Bran (1146S).	Brown		.00
12	July 15	A. C.	Bolls—buds, flowers.	Green	Yes	.077
13	July 15	A. C.	Leaves—a few buds and flowers.	Green	Yes	.293
14	July 15	A. C.	Stems—some leaves and young buds.	Green	Yes	.257
24	July 19	A. C.	Bolls—buds, flowers.	Green	Yes	.001
25	July 19	A. C.	Leaves—few buds and flowers.	Green	Yes	.056
58	July 19	A. C.	Stems—some leaves and young bolls.	Green	Yes	.010
6	July 28	A. C.	Bolls—buds and flowers.	Green	Yes	.001
7	July 28	A. C.	Leaves—some bolls and buds.	Green	Yes	.058
59	July 28	A. C.	Stems—some leaves and young bolls.	Green	Yes	.016
16	August 7	A. C.	Leaves—some bolls and seed.	Green	Yes	.021
15	August 7	A. C.	Bolls—some buds and flowers.	Green	Yes	.00
17	August 7	A. C.	Leaves few—(Stems.) and bolls.	Green	Yes	.019
18	Sept. 9	A. C.	Bolls—	Green	Yes	.016
19	Sept. 9	A. C.	Leaves—a very few bolls.	Green	Yes	.012
20	Sept. 9	A. C.	Stems—	Green	Yes	.012
99	Oct. 20	A. C.	Straw—	Brown	No	.004
27	Oct. 20	Blanchard	Stems—rich brown, no green	Brown	No	.003
28	Oct. 20th.	Blanchard	Leaves—tops.	Green	No	.000
84	Sept. 19th.	A. C.	Upper stems—minus leaves, cured indoors.	Green	No	.03
85	Sept. 19th.	A. C.	Upper stems—cured outdoors.	Green	No	.027
62	Sept. 27th.	Bolley's field	(Young flax samples, 1911), 1—1 ½-in. high volunteer.	Green	None	.252

TABLE VI.—DESCRIPTION OF FLAX SAMPLES ANALYZED.—1911—Continued.

Lab. No.	Collected Date	Source	Character of sample	Color	Bolls Present	Percent Prussic Acid
65	Sept. 27th.	Bolley's field	(Young flax samples, 2½—3-in. high volunteer.	Green	None	.238
80	Oct. 4th.	Bolley's field	(Young flax samples, 4-in. high volunteer.	Green	None	.183
88	Oct. 10th.	Bolley's field	(Young flax samples, 4½—5-in. high volunteer.	Green	None	.176
95	Oct. 16th.	Bolley's field	(Young flax samples, 5-in.+ high volunteer.	Green	None	.172
97	Oct. 20th.	Bolley's field	(Young flax samples, 5-in.+ frosted lightly.	Green	None	.163
98	Oct. 26th.	Bolley's field	(Young flax samples, 5-in.+ frosted severely.	Green	None	.135
63	Sept. 21st.	Bolley's field	Young flax samples, 2nd growth, 1—3-in. on stubble.	Green	None	.156
33	Sept. 14th.	A. C.	Very young flax (stems) short stems without well formed bolls.	Green		.028
23	Sept. 14th.	A. C.	Very young flax (leaves).	Green		.067
22	Sept. 14th.	A. C.	Very young flax (bolls).	Green		.001
57	Sept. 19th.	Fargo	Very young flax 3—6-in. leaves and stems.	Green	None	.139
77	Sept. 21st.	A. C.	Young flax 9-in. high, entire plant, very few buds and flowers.	Green		.142
78	Sept. 21st.	A. C.	Young flax 11-in. high, entire plant, very few young bolls, stems rather light colored (yellow).	Green		.252
79	Sept. 21st.	A. C.	Young flax, 14-in. high, entire plant, some quite large bolls.	Green		.122
94	Oct. 16th.	A. C.				.077

The question of the value of flax straw and screenings for use as feeding stuffs is discussed rather fully in a separate report, which takes up the subject irrespective of the presence or absence of prussic acid and its effect upon animals. Therefore, it is not the purpose here to treat of that part of the subject. The question of the toxicity of flax products when fed to animals will be discussed, though, in this connection.

As indicated in the previous reports made from this division, numerous references to the poisonous effect of young green flax material can be found in the literature pertaining to stock raising and to veterinary medicine. In fact many references can be found where flax seed and linseed meal or oil cake are attributed to have a toxic action upon cattle. It is true, of course, that oil cakes do not always have this effect and, therefore, there has been considerable difference of opinion about that particular feature of the flax seed.

Dr. Carl L. Alsberg, Chief of the Bureau of Chemistry of the U. S. Department of Agriculture, stated in a private communication to the writer that the question of the toxicity of flax seed occasionally came up in the routine work of the Poisonous Plant Division of the Bureau of Plant Industry,—when he was connected with that Bureau.

In order to find out the exact condition when linseed cake might prove toxic, Dr. S. J. M. Auld (England) carried on a series of experiments which he summarizes as follows:

"The majority of linseed cakes examined produced prussic acid on maceration with water, varying from 0.001% to 0.052%. In only a few cases was no prussic acid formed, owing to the enzyme having been destroyed. The "total" prussic acid content of the cakes examined varied from 0.023% to 0.056%. The rate of generation of hydrocyanic acid varies with different cakes, and is largely dependent on the temprature of incubation. The formation at blood-heat is extremely rapid, half of the available prussic acid being sometimes produced in fifteen minutes, and the maximum practically attained within six hours. The enzyme is easily destroyed by mixing the ground cake with boiling water and a linseed cake gruel properly prepared with boiling water develops practically no prussic acid, even after six hours.

"Yeast and yeast-containing feeds decompose the linseed glucoside and hasten the generation of prussic acid. All the green fodders examined, when in a finely divided condition, strongly inhibit the formation of prussic acid even when they contain glucosidoclastic* enzymes. The action is chiefly due to their crude fiber or cellulose. Salt, glucose, and molasses strongly inhibit the generation of prussic acid. Cane sugar is practically without effect.

"Of the conditions prevailing in the digestive tract, acidity and alkalinity both have inhibiting influence. The digestive enzymes also slightly retard the action by attacking the feeding stuff enzyme. The cyanogenetic glucosides phaseolunatin and amygdalin are non-toxic and are not hydrolyzed with the formation of prussic acid in the animal body.

"No fatal poisoning was observed by feeding sheep with linseed cake containing 0.052% of free prussic acid. When well soaked the material is refused by sheep even when hungry, and the moderate quantities taken after keeping the animals without food, induce slight poisoning. Death was induced in two sheep, weighing 50 lbs. and 80 lbs., by 7.8 and 3.9 grains of prussic acid, respectively. These quantities are equivalent in the former case to 2 lbs. and in the latter to 1 lb. of the linseed cake S (0.052% HCN)."

"From a due consideration of the results obtained, one is forced to the conculsion that when properly administered, linseed cake will have little poisonous action. . . . On the other hand, with the use, as a feeding stuff, of the material capable of producing 4 grains of prussic acid per pound, it is obvious that a certain amount of care must be exercised. Thus, fermented, mouldy, or yeast containing foods should be avoided for use with linseed or linseed cake. . . Gruel which has not been made with boiling water and which has been allowed to stand sometime before feeding, may well prove extremely dangerous, and particularly if given to calves which are not in good condition, is probably the cause of the few authenticated poisoning cases which have occurred."

From the same reference (Hydrocyanic Acid from Linseed Cake.)—"Cold pressed Linseed cake certified to yield 0.038 per cent of hydrocyanic acid was fed to a heifer at the rate of 14 lbs. daily for eight consecutive days without producing ill effects on the animal. A second heifer was fed a similar amount of hot-pressed cake certified to yield 0.032 percent of hydrocyanic acid, for a similar period with like results. It is pointed out that these rations are very much larger than would ordinarily be given and that the linseed cake contained an exceptionally high percentage of hydrocyanic acid.

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* The specific enzyme which decomposes the glucoside and produces the poison.

The results of investigations conducted to determine the effect of heat on the ferment giving rise to hydrocyanic acid in linseed, showed that the activity of the enzyme upon the cyanogenetic glucoside is the same after the seed has passed through the hot-press process as it was before."

These references indicate that apparently the conditions under which the flax materials are fed have a great deal to do with the liberation of the poison which is present. It is quite possible that the same conditions were active in the flax poison cases which occurred in North Dakota, tho in these instances linseed meal was not the substance fed.

In the present investigation, the writer endeavored to secure from the farmers and others, who co-operated with us in furnishing material, information as to whether they had ever fed flax straw or screenings, what the effect was upon the animals eating the same, and whether they knew of any case where flax poisoning had occurred. The data secured in answer to these questions is given in Table VII. While the experiences quoted are limited in number, yet they seem to be fairly favorable to the use of flax straw as roughage. Only one case of poisoning is reported and that happens to be one of the instances cited in a previous report. Mr. M. Toay, Jamestown, had deaths of sheep from, as he claims, tailings of flax run thru a fanning mill. This flax was very late and contained flowers, blossoms, bolls, unripe flax and ripe flax. The sample upon analysis showed 0.178% prussic acid and was used by this division in its feeding experiment upon a heifer which was fatally poisoned by the material.

Mr. A. E. Bergland, Hettinger, stated that in 1911 one cow which fed upon standing flax fell off in milk flow and almost dried up, even tho she was a fresh cow. After keeping in the barn and feeding hay for a while, the cow returned to normal milk supply.

A. Dahlbeck, Oakes, stated that in 1910 his flax crop was destroyed by hail. It grew up again to ordinary height and had bloomed and formed seed when frost overtook it. He cut some for hay and found that it served its purpose well, the cattle and horses relishing it and doing finely upon it. Even the hogs took great delight in eating the scattered leaves where the stack had stood.

E. Iwen, Amenia, wrote that the screenings he fed were mixed with grains and fed to hogs and cattle; that he threshes flax in the pasture and allows the cattle to eat all they want and that it does not hurt them.

D. Sinclair, Jamestown, declared that if frost strikes late flax while it is green, the straw seems to be spoiled for roughage. If the seed is not mature enough to be worth cutting the stock avoid the field as they would a weed patch.

Other farmers have stated also that cattle will not eat from a standing flax field. In Russia several cases of fatal poisoning from eating standing flax or mowed immature flax have been reported.

In 1911 at Grand Rapids ten cattle were made sick by eating one bushel of screenings,—of the ten, five died within forty minutes after eating the screenings.

The same year at Anamoose nineteen previously healthy cattle died within fifteen minutes after eating chaff from the cleaning of flax.

At Lankin, two cows died after eating a small amount of flax screenings.

At Williston, four head of cattle became sick from eating flax screenings,—of these one died within an hour, the other three slowly recovered.

At the Agricultural College in a feeding experiment a heifer was poisoned three times by the water extract from flax screenings. The third feeding was fatal, the animal dying in one and a half hours.

SUMMARY.

1. In this report is given an account of further experiments upon the poisonous principle contained in the flax plant.

2. Analyses of samples of flax straw, chaff, screenings, the entire plant, and young flax for the seasons of 1911 and

TABLE VII.—EXPERIENCES OF FARMERS IN FEEDING FLAX MATERIALS.

Co-operator	Town	Ever feed green flax straw	Results	Ever feed frosted flax, hay or straw	Results	Ever feed Flax screenings.	Results	Know of any case of animal poisoning from flax material	Further remarks
Reiten, L. R.	Hastings	Yes	None bad			No		No	See Report
Iwen, E.	Amenia	Yes	Good			Yes	Good	No	See Report
Dahlbeck, A.	Oakes	Yes	Very good					No	See Report
Reinholt, M.	McLeod	Yes	None bad	No		Yes	Cattle liked them but scoured	No	
*Toay, M.	Jamestown			Yes	Nothing marked	No		Yes	
Severeid, E. A.	Alsen	No		No		No		No	
Vandervee, Dr.	Pingree	Yes	None bad	Yes	None bad	No		No	
Bergland, A. E.	Hettinger	Yes	Satisfactory	Yes	Satisfactory	No			See Report
Deible, Geo.	Milton			No		Yes	Good	No	
Ketzman F. W.	Lakota	Yes	None bad	Yes	Good	Yes	None bad	No	See Report

* M. Toay, Jamestown. Name of farmer affected and town where this occurred.

1912 are reported with notes upon the character of the samples.

3. Some experiences of experiment station workers and farmers in regard to the toxic action of flax products are cited.

4. All flax materials evidently contain some of the poison, which varies with the stage of maturity of the flax, the part of the plant, and the species of flax, and also with some external conditions, such as weathering.

5. While this poison in flax substances may not always become liberated and active enough to be fatal to animals who eat it, nevertheless it is necessary for farmers to remember the possibility of fatal results, and feed only small quantities of the material until they are certain it will not kill their stock.

ACKNOWLEDGMENT.

The writer desires to acknowledge the assistance of the following in securing the data for this report.

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THE INFLUENCE OF BRAN-EXTRACTS ON THE BAKING QUALITIES OF FLOUR.

By H. L. White.

INTRODUCTION:—

It is generally recognized that bran and shorts contain valuable food constituents such as fat, carbohydrates other than cellulose, mineral matter and some nitrogenous material. Attempts have been made to improve the bread-making qualities of a flour, by introducing into the flour, extract of bran made with various solvents. Thus cold water extracts and hot water extracts[1] have been mixed with flour in varying proportions with beneficial results. A process has been patented[2] for treating bran in order to recover the mineral constituents for admixture with flour. The bran is treated with water to extract soluble salts and the residue treated with an acid solvent and water and subsequently with an alkaline solution. The acid and alkali solutions are neutralized, and the whole of the extracts are evaporated to dryness, and the residue reduced to a powder.

In connection with some experimental work on the mineral content of flour, it was found advisable to determine the effect of a dilute hydrochloric acid-extract of bran on the baking qualities of flour made from several varieties of wheat. It has been claimed[3] that a 0.2% HCl extract of bran contains phytin from which an acid identical with Posternak's[4] anhydro-oxymethylen diphosphoric acid is obtained. That phytin is obtained in this manner is denied by Anderson[5] who claims that the extract thus obtained does not correspond in composition with salts of the true phytic acid. Without entering into the discussion of this point, the fact remains that the dilute acid extract contains, in addition to other constituents, both organic and inorganic phosphorus compounds.

EXPERIMENTAL:—

The acid-extract used in these experiments was prepared by soaking bran in 0.2% HCl for sixteen hours. The proportions used were,—bran 300 grams, acid 1800 c. c. The liquid was first filtered through cheese-cloth and then through paper,—a clear liquid of a brown color being thus obtained. Analysis of this clear liquid gave the following results:—

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1. Willard and Swanson; Chemical News, 105, 97-99.
2. U. S. Patent, No. 1018441.
3. Patten and Hart; Bulletin 250, New York Exp. Station.
4. Posternak; Compt. Rend. 137; 439.
5. Anderson; Technical Bulletin No. 22, 1912. New York Agricultural Experiment Station.

TABLE I.—COMPOSITION OF ACID—EXTRACT OF BRAN.

Total solids. Grams Per 100 cc.	Ash Grams Per 100 cc.	Total P_2O_5 Grams Per 100cc.	Inorganic P_2O_5 Grams Per 100cc.	Organic P_2O_5 Grams (by diff.) Per 100cc.	Acidity N/20 NaOH 10 cc. Ext.
3.584	0.917	0.464	0.200	0.264	13.6

In one series of baking tests the acid-extract was neutralized with tenth-normal Na OH using phenolpthalein as an indicator. In another series a water-extract (bran 300 grams; water 1800 c. c.) was used; and in still another, 0.2% HCl was used in place of a bran extract. A comparison of these various extracts is afforded in the following table:

TABLE II.—COMPOSITION OF VARIOUS EXTRACTS USED IN BAKING TESTS.

	Total solids. Grams per 100 cc.	Ash Grams Per 100 cc.	Tota P_2O_5 Grams Per 100 cc.	Inorganic P_2O_5 Grams Per 100 cc.	Organic P_2O_5 Grams (by diff.) Per 100cc.	Acidity CC. N/20 NaOH for 10 cc. Ext.
Acid—Extract	3.584	0.917	0.464	0.200	0.264	13.6
Water—Extract	2.776	0.444	0.163	0.110	0.053	3.0
Acid—Extract neutralized	3.785	1.145	....	....	....	....
0.2 per cent HCl	....	....	....	....	....	10.65

BAKING TESTS:—

Several series of baking tests were made,—some months apart,—using flour form the same samples of wheat but freshly ground for each series of tests. In series I. (Spring of 1912) varying amounts of extract were used; while in series II (fall of 1912) the same amount (150 c. c.)

was used in every case. The bread was made in the usual way; the extracts being used instead of water to make the dough. A straight flour from each of three varieties of wheat was used in these experiments: Bluestem (Lab. No. 568), Durum (Lab. No. 481), and Velvet Chaff (Lab. No. 993).

TABLE III.—RESULT OF BAKING TESTS—SERIES I—BLUESTEM WHEAT.

ACID EXTRACT.

1st Baking	Extract cc.	Water cc.	Volume Loaf cc.	Color	Texture
568A. (check)	....	201	2460	95	96
568B.	80	123	2760	97	98
568C.	150	52	2820	100	100
568D.	150	50	3020	100	100

2nd. Baking. ACID EXTRACT.

568A. (check)	....	200	2460	95	96
568E.	80	120	2850	97	98
568F.	170	30	2920	98	100

3rd. Baking ACID EXTRACT NEUTRALIZED ("Soapy").

568A. (check)	....	196	2640	....	....
568G.	80	122	2590	....	....
568H.	170	36	2280	....	....

4th. Baking DILUTE HYDROCHLORIC ACID (0.2%).

568A. (check)	....	205	2690	99	98
568I.	80	121	2680	101	98
568J.	140	65	2700	99	97

In both the first and second bakings using acid-extract there was an increase in volume, amounting to 18%, and an improvement in both color and texture. With the neutralized acid-extract there was a decrease in loaf volume amounting to 13%.

In order to determine if the use of acid-extract resulted in an increase of acid-reacting material in the bread, the soft portions of loaves numbers 568A (check) and 568D (150 c. c. extract) were extracted with water and filtered solution titrated with .05 normal Na OH, with the following results:—

TABLE IV.—ACIDITY OF INNER PORTIONS OF LOAVES OF BREAD.

Lab. No.	N/20 NaOH cc.	Calculated as Lactic Acid Percent	Calculated as Hydrochloric Percent
568A. (check)	4.3	.193	.078
568D. (extract)	8.35	.373	.152

The average acidity of the inner portion of twenty-one samples of fresh bread was found[1] to be equivalent on a dry basis to 0.289% lactic acid or 0.215% hydrochloric acid. Therefore, the acidity of the water soluble portions of 568A and 568D is about the same as the average of home-made bread and of bakers bread.

TABLE V.—SERIES I—DURUM WHEAT. ACID EXTRACT.

1st Baking	Extract cc.	Water cc.	Volume Loaf cc.	Color	Texture
481A (check)	....	190	2040	97	94
481B.	80	107	2090	97	95
481C.	140	51	2170	97	96

This flour did not respond to treatment with acid-extract as the gain in loaf volume was only 5%, color and texture remaining about the same in each loaf.

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[1] Congdon:—Twenty-second Annual Report, North Dakota Agricultural Experiment Station (1911) Part 11.

TABLE VI.—SERIES I VELVET CHAFF WHEAT.

ACID EXTRACT.

1st Baking	Extract cc.	Water cc.	Volume Loaf cc.	Color	Texture
993A. (check)	....	190	1980	96	92
993B.	80	110	2260	99	96
993C.	160	30	2400	98	96
2nd. Baking ACID EXTRACT.					
993A. (check)	....	187	2090	96	95
993D.	80	108	2340	97	98
993E.	150	38	2380	98	98
3rd. Baking ACID—EXTRACT NEUTRALIZED.					
993A. (check)	....	190	2200	100	93
993F.	80	113	2090	99	92
993G.	140	55	1970	99	90
4th Baking DILUTE HYDROCHLORIC ACID (0.2%).					
993A. (check)	....	187	2090	96	95
993H.	80	108	2230	97	95
993I.	150	38	1910	94	85

As shown in the above table there was an increase in the loaf volume of from 13% to 21% when acid-extract was used, and both color and texture were improved. With neutralized extract there was a decrease in loaf volume. With dilute acid alone there was a decrease of 9% in loaf volume, a slight change in color, and a poor texture.

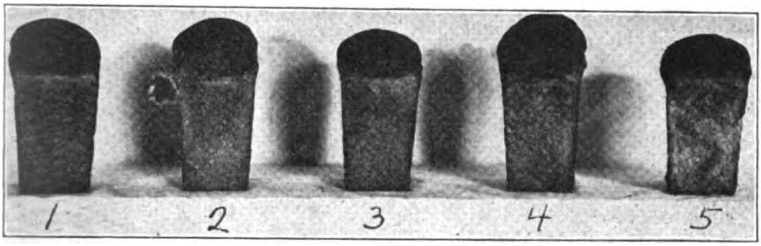
After a study of these results, it was decided to make a second series of baking tests, including in each baking all of the extracts which had been used in the several bakings of series I and in addition a filtered cold-water-extract of bran.

TABLE VII.—SERIES II.—BLUESTEM WHEAT—NO. 568.

Flour No. 568	Extract cc.	Water cc.	Volume Loaf cc.	Color	Texture
Check	....	190	2490	94	97
Check	....	189	2480	95	97
Acid Extract	150	40	2600	96	98
Acid Extract	150	40	2690	96	98
Water Extract	150	40	2600	92	98
Water Extract	150	39	2515	93	97
Acid Extract Neutral	150	39	2240	94	92
Acid Extract Neutral	150	45	2360	92	92
Dilute Acid	150	39	2250	94	90
Dilute Acid	150	40	2200	94	90

A consideration of data submitted in Table VII shows that the acid-extract and water-extract gave somewhat larger loaves than the check, in the order named; and that with the acid-extract both color and texture were slightly improved. Plate I gives some idea of the external appearance of the loaves.

PLATE I.



BAKING SERIES II—BLUESTEM WHEAT.

See Plate I.

No. 1—Check Loaf.
No. 2—Water-extract.
No. 3—Acid-extract, neutralized.
No. 4—Acid-extract.
No. 5—Acid alone.

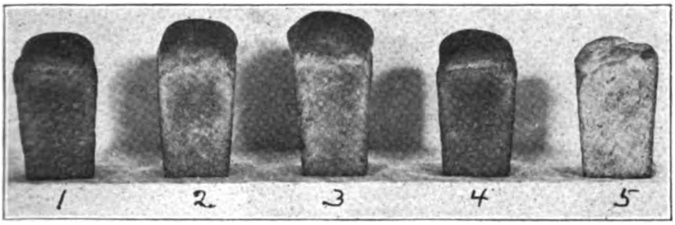
TABLE VIII.—SERIES II.—DURUM WHEAT.

Flour No. 481	Extract cc.	Water cc.	Volume Loaf cc.	Color	Texture
Check	....	200	1920	96	95
Check	....	199	1870	96	95
Acid-Extract	150	48	2030*	96	94
Acid-Extract	150	51	1870*	96	98
Water-extract	150	50	2010	95	96
Water-extract	150	51	2030	95	96
Acid-extract neutralized	150	51	1910	97	96
Acid-extract neutralized	150	51	....	....	....
Dilute Acid	150	50	1630	94	85
Dilute Acid	150	50	1650	94	85

* (Bakers Comment: "Dough broke slightly.")

A consideration of the data submitted in Table VIII indicates but little improvement in loaf volume, color, or texture by the use of acid-extract. The water-extract gave better results than the acid extract. The dilute acid decreases loaf volume and unfavorably modifies the texture.

PLATE II.



BAKING SERIES II—DURUM WHEAT.

See Plate II.

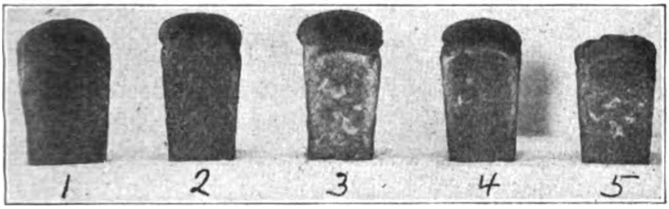
No. 1—Check Loaf.
No. 2—Water-Extract.
No. 3—Acid-Extract.
No. 4—Acid-Extract, neutralized.
No. 5—Acid alone.

TABLE IX.—SERIES II.—VELVET CHAFF WHEAT.

Flour No. 993	Extract cc.	Water cc.	Volume Loaf cc.	Color	Texture
Check	....	188	2030	95	95
Check	....	187	2060	95	95
Acid-Extract	150	36	2480	98	97
Acid-Extract	150	36	2460	98	97
Water-Extract	150	36	2340	94	96
Water-Extract	150	34	2200	94	96
Acid-Extract neutralized	150	35	2020	95	95
Acid-Extract neutralized	150	36	2040	95	95
Dilute Acid	150	36	1870	92	80
Dilute Acid	150	36	1700	92	80

As will be noted in Table IX, the acid-extract exerted a favorable influence on the baking qualities of flour from Velvet Chaff Wheat, increasing the loaf volume, and giving a better color and texture. The water-extract increased loaf volume, but had little influence on color and texture. The dilute acid on the other hand had a marked unfavorable influence on loaf volume and texture, and, to a lesser degree, the color.

PLATE III.



BAKING SERIES II—VELVET CHAFF WHEAT

See Plate III.

No. 1—Check Loaf.
No. 2—Water-Extract.
No. 3—Acid-Extract.
No. 4—Acid-Extract, neutralized.
No. 5—Acid alone.

In view of the fact that in the larger number of baking tests the acid-extract had a greater influence than the water-extract to increase loaf volume and to improve color and texture, the question naturally arises as to whether the improvement is due to the stimulating effect of acid, or phosphate, or other constituent of the extract on the yeast; or to some other factor. Experiments undertaken to determine the stimulating effect of acid-extract on yeast were not convincing. A possible explanation is that the gluten may have become more coherent in the presence of acid and soluble salts (particularly phosphates) as is suggested by Wood.[1] At any rate, the baking tests show clearly that it is not acid alone, but acid plus extractive material that gives the best results.

SUMMARY AND CONCLUSIONS.

In two series of baking tests of flour made from three varieties of wheat, acid-extract of bran, water-extract, acid-extract neutralized and dilute acid, were used to replace a part of the water necessary to make the dough.

In general the acid-extract produced larger loaves of bread (from 6% to 20% increase in volume) of a better color and texture than the check loaf, or those in which other extracts were used. The water-extract produced loaves somewhat larger than the check loaves. The dilute acid gave a loaf of decreased volume and very poor texture.

Analyses of acid- and water-extracts show the presence of 0.464 grams $P_2 O_5$ and 0.163 grams $P_2 O_5$ respectively, in 100 c. c. extract.

Experiments made to show the stimulating effect of acid-extract on yeast were not convincing. It is thought the presence of both acid and soluble salts makes the gluten more coherent.

In general the better the flour, that is the stronger the gluten,—the more marked is the improvement by use of acid-extract; but all samples of flour show greater or lesser improvement.

The inner portions of the loaves of bread made with acid-extract show no greater amount of water-soluble acid reacting material than the average of home-made, or baker's bread.

In conclusion the writer wishes to acknowledge his indebtedness to L. M. Thomas of the Division of Grain Standardization Bureau of Plant Industry, U. S. Dep. of Agriculture, for his co-operation in making the baking tests, scoring the bread and for making the photographs that are used in this report.

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[1] T. B. Wood, Jour. Agricultural Science 2; 267 (1907) Abstract in Jour. Soc. Chemical Industry, 27; 175 (1908).

THE PHOSPHOROUS CONTENT OF WHEAT AND OF WHEAT FLOUR; AND ITS RELATION TO THE BAKING QUALITIES OF THE FLOUR.

By H. L. White and R. F. Beard.

I—WHEAT FLOUR.

Introduction:

The nitrogen content of wheat and of flour has been thoroughly studied and the significance of its variations as related to the baking qualities of the flour has been pointed out by many observers. The question naturally arises as to whether the amounts of the compounds of phosphorus in wheat and flour likewise bear any definite relation to volume and color of resulting loaf. The writer realizes very fully the importance of many other factors, physical and chemical, in their effect upon the baking qualities of flour; but to clear the way for further investigations a determination of the amounts of phosphorus and their relation, if any exists, to the baking qualities of the flour, seems of fundamental importance. The fact that many "flour improvers" contain some phosphorous compounds, together with the effect of dilute acid extracts of bran containing phosphorus on the baking qualities of flour, was a further incentive to work along this line.

In this connection it has been considered advisable to limit the investigation chiefly to wheat grown in North Dakota. In this state Hard Spring Wheat and Durum Wheat are grown extensively; and the sub-stations and demonstration farms connected with the State Agricultural Experiment Station are able to furnish samples of standard varieties grown under known conditions and in several systems of crop rotation. Hard Spring Wheat is recognized as having, generally, a strong gluten and is often used to strengthen the soft wheats grown in other localities. In this report, therefore, only two characteristic varieties of wheat grown in North Dakota are considered.

Experimental:

The flours selected for analyses were of two grades,—

patent and straight,—of both hard wheat and durum. The total phosphorus was determined on the ash from five grams of flour by the usual method, using ammonium molybdate and magnesium mixture.

The water soluble phosphorus was evaporated to dryness, ashed over a low flame and determined volumetrically by the official method (Bulletin 107 Revised). The inorganic phosphorus was determined by Collison's[1] method and organic phosphorus by difference.

TABLE I.—MOISTURE, ASH, NITROGEN AND PHOSPHORUS CONTENT OF WHEAT FLOUR.

HARD WHEAT PATENTS.

Lab. No.	Ash Percent	Moisture Percent	Nitrogen Percent	Total P_2O_5 Percent	Water Soluble P_2O_5 Percent	Inorganic P_2O_5 Percent	Organic P_2O_5 Percent
512	.516	9.78	2.35	.286	.230	.0291	.2569
628	.496	10.45	1.75	.228	.082	.0197	.2083
631	.517	10.23	2.20	.222	.074	....	....
655	.589	10.75	2.35	.235	.101	.0195	.2155
664	.491	11.11	2.31	.182	.058	.0261	.1559
687	.557	9.61	2.37	.756	.091	.0156	.7404

HARD WHEAT STRAIGHTS.

Lab. No.	Ash Percent	Moisture Percent	Nitrogen Percent	Total P_2O_5 Percent	Water Soluble P_2O_5 Percent	Inorganic P_2O_5 Percent	Organic P_2O_5 Percent
670	.665	8.91	1.91	.318	.167	.0183	.2997
677	.606	8.44	1.90	.292	.156	.0172	.2748
678	.626	9.68	1.90	.326	.139	.0332	.2928
682	.618	8.99	1.99	.372	.137	.0283	.3437
665	.566	9.41	1.92	.298	.114	....	....

DURUM PATENTS.

Lab. No.	Ash Percent	Moisture Percent	Nitrogen Percent	Total P_2O_5 Percent	Water Soluble P_2O_5 Percent	Inorganic P_2O_5 Percent	Organic P_2O_5 Percent
456	.796	10.03	2.38	.477	.134	....	....
578	.723	9.74	2.90	.352	.182	.0196	.3324
606	.692	10.29	2.68	.329	.126	....	....
609	.600	11.41	2.51	.360	.152	.0305	.3295
640	.732	10.73	2.54	.346	.168	.0247	.3213
690	.644	11.13	2.77	.319	.133	.0231	.2959
649	.669	9.79	....	.320	.178	....	....
481F	.726	9.36	2.77	.356	.207	.0350	.321
645	.963	8.87	....	.490	.215	....	....
640	.808	8.29	....	.370	.170	....	....
482E	.858	8.58	2.37	.418	.274	.0450	.373

The data presented in Table I. shows a wide variation in phosphorus content; in some cases, notably in numbers 687, 664, and 512, so great as to call for a careful checking up of method and of records without, however, finding any reason for such wide variations. In general the amounts of inorganic P_2O_5 are more uniform (shown better in Table II.) One worker[2] in this field claimed to find no mineral phosphates in eighteen samples of flour examined.

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[1] R. C. Collison: Journal of Ind. and Eng. Chemistry 4, No. 8 (1912).

In Table II. the groups of phosphorus are calculated to a moisture free basis, and the percentage relations to the total phosphorus shown.

TABLE II.—RELATION OF DIVISIONS OF PHOSPHORUS IN WHEAT FLOUR TO THE TOTAL PHOSPHORUS.

HARD WHEAT PATENTS.
(Moisture-free basis.)

Lab. No.	Total P_2O_5 Percent	Organic P_2O_5 Percent	Inorganic P_2O_5 Percent	Water Sol. P_2O_5 Percent	Percentage Relation			
					Total P_2O_5	Organic P_2O_5	Inor-ganic P_2O_5	Water Soluble P_2O_5
512	.317	.285	.032	.255	100	90.0	10.0	80.0
628	.254	.232	.022	.091	100	91.4	8.6	35.8
631	.247	....	....	.082	100	....	....	33.2
655	.262	.241	.021	.113	100	92.0	8.0	43.1
664	.204	.175	.029	.065	100	85.8	14.2	31.8
687	.836	.819	.017	.106	100	98.0	2.0	12.6
				HARD WHEAT STRAIGHTS.				
670	.349	.329	.020	.183	100	94.3	5.7	52.4
677	.318	.300	.018	.170	100	94.4	5.6	53.4
678	.360	.324	.036	.153	100	90.0	10.0	42.5
682	.408	.377	.031	.150	100	92.4	7.6	36.7
665	.328	....	....	.125	100	....	....	38.1
				DURUM PATENTS.				
456	.530	....	....	.148	100	....	....	28.0
578	.389	.368	.021	.201	100	94.6	5.4	51.6
606	.366	....	....	.140	100	....	....	38.2
609	.406	.372	.034	.170	100	91.7	8.3	41.8
640	.387	.360	.027	.188	100	93.0	7.0	48.5
690	.358	.332	.026	.149	100	92.8	7.2	41.6
				DURUM STRAIGHTS				
649	.354	....	....	.197	100	....	....	55.6
481F	.392	.349	.043	.228	100	89.1	10.9	58.1
645	.537	....	....	.235	100	....	....	43.7
640	.403	.377	.026	.185	100	93.6	6.4	45.9
482E	.457	.408	.049	.299	100	89.3	10.7	65.4

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[2] P. Rengniez: Thesis, School of Pharmacy, Paris, Cited in Rev. Sci. 49, 176—7.

TABLE III.—COMPARISON OF DIVISIONS OF PHOSPHORUS WITH VOLUME AND COLOR OF BREAD—TWO VARIETIES OF WHEAT AND TWO GRADES OF FLOUR.

(Phosphorus on Moisture-free basis.)

Lab. No.	Total P_2O_5 Percent	Organic P_2O_5 Percent	Inorganic P_2O_5 Percent	Water Soluble P_2O_5 Percent	Volume	Color
664	.204	.175	.029	.065	2750	103
687	.836	.819	.017	.106	2640	100
512	.317	.285	.032	.255	2580	97
631	.247	....	....	.082	2490	96
670	.349	.329	.020	.183	2350	98
677	.318	.300	.018	.170	2340	98
665	.328	....	....	.125	2330	97
628	.254	.232	.022	.091	2310	100
682	.408	.377	.031	.150	2310	99
678	.360	.324	.036	.153	2300	97
655	.262	.241	.021	.113	2270	105
456	.530	....	....	.148	2200	96
482E	.457	.408	.049	.299	2190	90
690	.358	.332	.026	.149	2100	100
609	.406	.372	.034	.170	2080	94
481F	.392	.349	.043	.228	1990	94
578	.389	.368	.021	.201	1950	94
606	.366	....	....	.140	1880	82

From a study of Table III. it would seem that in general, total, organic, and water soluble phosphorus vary inversely as the loaf volume.—Inorganic phosphorus does not show such a variation. In order to bring this out more clearly the average results may be tabulated in two groups, dependent upon the volume of the loaves, and in Table IV. such division is made.

TABLE IV.—COMPARISON OF AVERAGE AMOUNTS OF THE DIVISIONS OF PHOSPHORUS WITH LOAF VOLUME, LOAVES ARRANGED IN TWO GROUPS ACCORDING TO VOLUME.

Volume cc.	Total P_2O_5 Average Percent	Organic P_2O_5 Average Percent	Inorganic P_2O_5 Average Percent	Water Soluble P_2O_5 Average Percent
1880 to 2270	0.395	0.345	0.032	0.181
2300 to 2750*	.309	.289	.027	.140

* Sample No. 687 is omitted from the average.

These results are based upon a comparison of absolute amounts of phosphorus; but if a comparison be made based upon the relative amounts of phosphorus compared with total phosphorus, it is found that the larger loaf volumes are associated with a high percent of the total phosphorus in an organic form.

TABLE V.—COMPARISON OF VOLUME AND COLOR OF LOAF WITH PROPORTIONS OF PHOSPHORUS IN FLOUR.
(Total P_2O_5 = 100).

Lab. No.	Total P_2O_5	Organic P_2O_5	Inorganic P_2O_5	Volume	Color	Water Soluble P_2O_5
664	100	85.8	14.2	2750	103	31.8
687	100	98.0	2.0	2640	100	12.6
512	100	90.0	10.0	2580	97	80.0
631	100	....	....	2490	96	33.2
670	100	94.3	5.7	2350	98	52.4
677	100	94.4	5.6	2340	98	53.4
665	100	....	....	2330	97	38.1
628	100	91.4	8.6	2310	100	35.8
682	100	92.4	7.6	2310	99	36.7
678	100	90.0	10.0	2300	97	42.5
655	100	92.0	8.0	2270	105	43.1
456	100	....	....	2200	96	28.0
482E	100	89.3	10.7	2190	90	65.4
690	100	92.8	7.2	2100	100	41.6
609	100	91.7	8.3	2080	94	41.8
481F	100	89.1	10.9	1990	94	58.1
578	100	94.6	5.4	1950	94	51.6
606	100	....	....	1880	82	38.2

If the results shown in Table V be grouped into two divisions according to loaf volume and averages obtained, the relation of percentage of organic phosphorus to loaf volume is brought out.

TABLE VI.—COMPARISON OF LOAF VOLUME WITH PERCENTAGE RELATIONS OF DIVISIONS OF PHOSPHORUS.

Volume cc.	Total P_2O_5 Percent	Organic P_2O_5 Percent	Inorganic P_2O_5 Percent	Water Soluble P_2O_5 Percent
(1880 to 2270)	100	87.3	8.1	45.8
(2300 to 2750)	100	93.5	8.7	45.3

SUMMARY.

Determinations were made of total phosphorus, organic phosphorus, inorganic phosphorus, and water soluble phosphorus in flour from two varieties of North Dakota grown wheat. A marked variation in all these divisions of the phosphorus content was found. A comparison of phosphorus content with loaf volume was made. Summarizing the data obtained, it is found in general that the larger loaves contain less of all divisions of phosphorus than the smaller loaves. Calculated on the basis of total phosphorus equal 100%, it is found that the larger loaves contain a higher per cent of organic phosphorus than the smaller loaves, the averages of two groups being 93.5% for the larger and 87.3% for the smaller.

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